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TRAGOPOGONS AS WEEDS IN CANADA[1]

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The Tragopogons (Family Compositae) are Old World plants ranging from the western Mediterranean region to western Asia and Siberia, several species also having become established in North America. These latter are all stout, erect, smooth plants, commonly from one to three feet in height, with flower heads and fruit terminating the branches and bearing some resemblance to those of dandelion. Stalks are produced from more or less fleshy, biennial tap-roots.

HISTORY

The earliest available Canadian reference is one to *Tragopogon porrifolius* L. by Provancher (10) and this only to its cultivation as salsify or vegetable oyster. As an escape *T. pratensis* L., the yellow goatsbeard, was recorded in 1867 by Hubbert (7). Billings' list for Ottawa in 1866 (2) did not include either plant but Fletcher (4) refers to both, the specimens having been collected respectively by himself and his associate, J. A. Guignard in 1879, and remaining in the herbarium of the Division of Botany, Ottawa. The original station for *T. pratensis* was "Along the railway track near the St. Louis dam, Ottawa." Older residents will recall this as the north end of Dow's Lake, now a portion of the Federal District Commission driveway. Occurrence along this section of railway is still about as abundant as anywhere in the city and district.

Macoun (9) assembled records also for *T. pratensis* at St. Stephen, N.B. and Pictou, N.S.; and for *T. porrifolius* at Belleville, London and Strathroy, Ont. In Part III of his Catalogue (1886) he added for *T. porrifolius*: "Around Lotbiniere, Que. (*St. Cyr*). Victoria, Vancouver Island. (*Fletcher*)." Both plants have become more generally distributed but remain comparatively unknown to the general public.

Rydberg in 1917 (11) listed a third species, *T. dubius* Scop. (known as greater goatsbeard in Europe), as being escaped in Colorado. A note by Hull (8) recording its detection in Indiana in 1943 carries an editorial footnote: "This large-headed species, *Tragopogon dubius* Scop. (1772), including *T. major* Jacq. (1773) has recently been sent to the Gray Herbarium from Virginia, Michigan, Illinois, Minnesota, South Dakota, Oklahoma, Texas, Washington, Oregon and California.' *T. major* here, and as used by some American botanists, appears to be equivalent to *T. dubius* Scop. as treated by Hegi (6) to equal *T. major* Jacq. and *T. dubius* Scop. subsp. *major* (Jacq.) Vollm. If two entities are present here they have not been clearly separated.

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DISTRIBUTION

Old World distribution of the three plants is not closely conterminous. *T. porrifolius*, being widely cultivated, is also in such places escaped. *T. pratensis* ranges, according to Hegi (6), from Ireland, Denmark and much of Scandinavia to northern Karelia in Russia, on the north, to middle Spain, Italy, Macedonia and south Russia; also in the Caucasus, Armenia, western Persia and Siberia. *T. dubius* is in northern France, across Germany to West Prussia and Poland, and southward to Spain, middle Italy, the Balkans and south Russia, and extending to Asia Minor and the Caucasus; a generally less northern range than that of *T. pratensis* although in Valais, southern Switzerland, where both occur, reaching a little higher altitude than the other.

In North America about the same situation holds with regard to latitude. *T. pratensis* ranges, according to the manuals, from New Brunswick to Manitoba and south to New Jersey and Colorado. *T. dubius*, as as well as in the States enumerated above, extends northwestward into Canada, a zonal trend common among biological forms and not inconsistent with the conclusion that *T. dubius* occupies the less high latitude of the two.

In Canada *T. dubius* was being confused at first with *T. pratensis* but has been distinguished in the western provinces for about ten years. A specimen was collected by the writer at Beaverlodge, Alta., in 1934; and another, with immature flower, secured at Lethbridge, Alta., in 1929 appears to be this. In the East it was not detected until 1943, although a specimen sent from Rondeau Park in 1942 and another collected near Brantford, Ont., a year earlier by W. H. Minshall both prove to be this species. In the Ottawa district suspected presence of both yellow-flowered goatsbeards was confirmed when they were found in 1945 growing together at Westboro between the C.P.R. tracks and the Ottawa River, and for two miles into the city. Both species were also growing two miles south near City View and across the river at the Hull Armouries and near the Canada Cement Company quarries, a total span, north and south of about five miles. Scouting up to six or eight miles in all directions from the city has failed to locate any more *T. dubius* although the longer known plant is found along most roads. About the same date a second Quebec station was found for *T. dubius* by C. Frankton near Ville St. Pierre, outside of Montreal. Later in the summer a specimen from Fitzroy Harbour, Ont., was found to be this species; and a light field infestation five miles east of Renfrew still further extended the known range in eastern Ontario. With closer discrimination than formerly, specimens have now been added to the Division herbarium from seven counties in Ontario: Renfrew, Carleton, Hastings, York, Simcoe, Brant and Kent; and in Quebec from Gatineau and Jacques Cartier counties.

From herbarium evidence *T. pratensis* would be in Ontario the predominant, and eastward practically the only, species. On the prairies, however, and in the drier parts of British Columbia *T. dubius* is the more prevalent. On a survey west to Saskatoon, Rosetown and Regina in early summer, 1945, it was first recognized near the Ontario-Manitoba boundary and was the only one seen westward. According to Russell (5) it "has become much more abundant and widely distributed in the province (Saskatchewan) during the past ten years."

INCIDENCE

Both species tend to be in colonies in this country as well as in Europe. *T. pratensis* is reported to occur in its native habitat from somewhat moist, well-fertilized meadows to drier slopes, waysides, waste places and occasionally in fields; *T. dubius* on dry stony slopes and even quarries, walls and road embankments, and freight yards, as well as in open woods, stream banks, meadows and vineyards. This species, perhaps both, are commonly on chalk or lime. The impression conveyed is that *T. dubius* endures generally drier, more adverse conditions than the other species, and this, broadly, is what is indicated in Canada.

Weed surveys, while well able to distinguish Tragopogons from other plants and, at least when in flower, to distinguish *T. porrifolius* from the others by colour, were not, unfortunately, in earlier years taking account of two yellow goatsbeards For this reason survey data for these two are merged in Table 1. By meridional belts percentage incidence (surveys of each 100 in which recorded) is seen to vary from almost nil in the central belts to figures for the rest still low as compared with most noxious weeds.

TABLE 1.—PERCENTAGE INCIDENCE IN CANADA

131-116° B.C. and Peace R. 642 surv.	115-108° Alta. and W. Sask. 317 surv.	107-100° Sask. and W. Man. 341 surv.	99-92° Man and W. Ont. 167 surv.	91-84° Superior region 101 surv.	83-76° Cent. Ont. and N. Que. 902 surv.	75-68° E. Ont. and Cent. Que. 840 surv.	67-60° Maritimes and Gaspe 1005 surv.
%	%	%	%	%	%	%	%
T. dubius (west largely) and *T. pratensis*							
9.0	3.7	4.7	2.9	1.0	9.5	11.6	10.5
T. porrifolius							
1.4	.3	0	2.4	0	3.2	0	0

Although 10% may seem light incidence it must be remembered that it consists commonly of rather dense occurrence within more localized distribution than that of many other weeds. All three frequent waysides (road and railway) with increased density in proximity to towns and heavier traffic. Less frequently infestations occur in thin sod and even in crops as shown in Figure 1 where a field was completely over-run by *T. dubius*.

For *T. porrifolius*, a more domesticated plant than the others, lighter incidence is shown, and was found mostly in Ontario, south central Manitoba and in the upper Okanagan and coastal parts of British Columbia. Higher incidence, for *T. pratensis* in the East and for *T. dubius* over much of the West, indicates for these somewhat readier naturalization and, apparently, some ecological specialization although they grow together quite well in Ontario. The failure of *T. pratensis* to colonize the prairies, as *T. dubius* has done in a much shorter period and is doing both eastward and westward, points to the latter as the greater potential weed.

Under Ottawa conditions *T. porrifolius* was seen sparingly only along roadsides through fertile land. The others were in less restricted habitat, and without much dwarfing of either on the shallowest soil or on railway ballast. Almost bare limestone supports them. On the hot, dry plains of the West, plants of *T. dubius* are often forced into bloom at a few inches in height. *T. pratensis*, on the other hand has been seen up to five or six feet in height near Ottawa under the dense shade of roadside trees. Marked sensitivity to sunlight is shown by the bending of heads to the morning sun and their closing by noon unless delayed by a change to dull or rainy weather. Noon-flower or go-to-bed-at-noon are colloquial names expressive of this trait. Commonly the more slender peduncles of *T. pratensis* are found bent and twisted permanently as a result of such daily light response.

DESCRIPTION

Descriptive remarks for those unfamiliar with these species will be confined to the field characters useful for their separation since they are not often confused with other plants. Those found most helpful are summarized in Table 2.

TABLE 2.—FIELD CHARACTERS USEFUL IN IDENTIFICATION OFTEN LOST IN DRIED SPECIMENS

Characters	*T. pratensis*	*T. dubius*	*T. porrifolius*
Flower colour (yellows of Horticultural Colour Chart (3))	Canary yellow	Sulphur yellow	Purple
Peduncle	Little thickened, often flexuous	Thick, stiff, fistulose	Thick, stiff, fistulose
Involucral bracts	Equalling florets, broad, tinged with purple	Longer than florets, narrow, without purple	Longer than florets
Fruit (including beak and, with pappus, determining size of globes)	Mostly under 20 mm. long	Mostly over 20 mm. long	
Stalk	Tending to purplish in full light, especially on nodes	Seldom purplish except at base	
Leaf tips (at all ages)	Usually curved or curled	Straight and grass-like	Straight

WEED CHARACTER

The three species are all offenders against private and civic pride in well-kept surroundings; and *T. dubius* has provided enough instances of field infestation to warrant close vigilance concerning it. They are all prolific of seed which has been found, in the case of *T. pratensis* (1), to have almost perfect germination at maturity and continuing high for several years. Germination in nature seems to be restricted, by seed-bed

requirements no doubt, to just those scarred embankments and waste places, not too densely turfed, which are commonly found infested. Tilled land would provide the seed-bed but, unless sowed to a crop like fall wheat, rye or hay, that leaves it undisturbed through a second season, it does not survive to reproduce. Maintenance of roadsides in close sod and better clean-up of breeding places of weeds would restrict its area. Mowing to prevent seeding should commence with early blooming and needs to be repeated later for secondary growth. Up-rooting is therefore even better and, with such erect plants, is feasible by hand if not by implements.

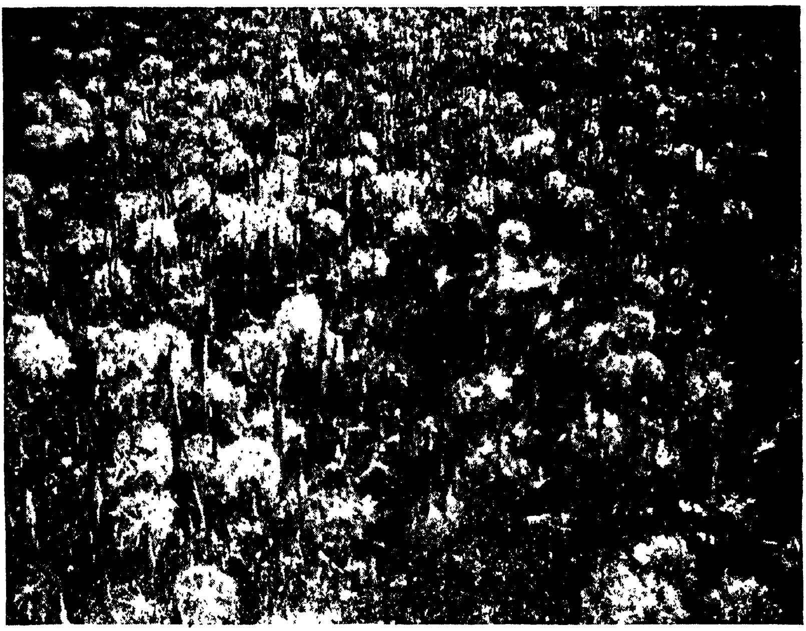

FIGURE 1 *T. dubius* infestation in crop, upper grass zone, Brigade Lake district near Kamloops, B.C.

SUMMARY

The history, present distribution and status in Canada of three species of *Tragopogon* are discussed. *T. dubius*, of fairly recent introduction and still largely of the drier West, appears to exhibit marked weed tendencies, *T. pratensis* remains still, after three-quarters of a century, mostly a wayside and waste place encumbrance, and *T. porrifolius* a sparing escape from cultivation.

Practical field characters for distinguishing the species are given. Ecology, life history and control are only lightly touched upon pending further investigation. As biennials, with abundant seed of high germination capacity, the infrequence of field infestation is believed due to less success in finding a seed-bed than in loose, often bare, vacant lot and wayside sites.

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CONTRIBUTIONS TO THE STUDY OF RANCIDITY IN CANADIAN CHEDDAR CHEESE[1]

III. A COMPARISON OF THE LIPOLYTIC ACTIVITY OF SLIGHT RANCID AND FIRST GRADE SAMPLES

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In seeking to assess the possible role of milk lipase as a causal agent in the production of rancid cheese, the suggestion was made by Hammer (4) that rancid cheese might show greater fat hydrolysing activity when introduced into sucrose-cream mixtures than would cheese of normal flavour. Investigators of lipase activity in cheddar cheese have so far not studied the problem from the point of view of enzyme activity of the cheese itself (5, 10, 13). Gould (3) has shown that the lipase content of milk is identified with the skimmilk fraction and accordingly one might expect much of this enzyme to pass into the whey. On the other hand, the fact that a slow fat hydrolysis can be demonstrated in raw milk cheese (7, 10) would appear to be sufficient grounds for investigating rancidity in cheese with this point in view.

EXPERIMENTAL

Determinations of lipase activity were made on two sets of samples. The first of these comprised 19 samples, 4 of which were graded 41-94 or higher, while the remainder were all of second grade quality having been scored down as a result of either slight rancid, fruity, not clean, or off flavours. When held for 5 days in a sucrose-cream preparation at 98° F. it was not possible to show significant differences in the acidities of these mixtures. This work was of a preliminary nature and will not be further described.

The second series of samples consisted of three 1-pound blocks of first grade cheese and three 1-pound blocks of second grade, slight rancid cheese. All of these samples were manufactured during the period of October 13-19, 1942 and the analysis was carried out on them between November 13 and December 4. Preliminary to determining lipase activity the samples were analysed for fat by the Mojonnier Method (11), for total solids by the A.O.A.C. method (1), and for pH by means of glass electrode and a Coleman electrometer. In addition the acidity of the cheese fat was determined. The determination consisted of grinding about 250 g. of the cheese to be tested in a kitchen food chopper, the ground cheese then being allowed to oil off by placing it in a tall 400 ml. beaker in a water-bath at 125° F. for $2\frac{1}{2}$ to $3\frac{1}{2}$ hours. Twenty grams of the fat obtained by this means was then dissolved in 50 ml. of neutral alcohol, brought to a boil over hot water, and immediately titrated against 0.1N NaOH using 0.5 ml. of phenolphthalein as indicator. This titration has been used by Breazeale and Bird (2) in butter deterioration studies. The results of these determinations are presented in Table 1.

[1] Contribution from the Dairy Department.
[2] Lecturer.

TABLE 1.—VALUES FOR FAT, TOTAL SOLIDS, FAT ACID VALUE AND pH ON SIX SAMPLES OF CHEESE STUDIED FOR LIPASE ACTIVITY

Sample	Flavour	Fat	Total solids	Acidity of cheese fat	pH
		%	%		
1	Clean	34.17	65.95	2.85	5.18
2	Clean	36.02	67.85	2.30	5.17
3	Clean	34.50	65.51	2.53	5.04
4	Sl. rancid	34.81	65.76	3.33	5.11
5	Sl. rancid	35.20	65.84	2.70	5.05
6	Sl. rancid	34.92	66.60	2.75	5.20

The sucrose-cream mixture was prepared as follows. Cream testing 37% fat was secured and the amount of water present calculated. Cane sugar in an amount equal to twice the weight of the water present was then stirred in until dissolved. To facilitate solution of the sugar, the mixture was heated to 150° F. after which it was held for 1 hour. While still at this temperature, the mixture was homogenized by passage through an "Empire" cream maker. The reaction was then brought to pH 8.2 by the addition of 0.2N NaOH solution after which it was dispensed into 6-ounce bottles in 100 ml. amounts. These were then held in an atmosphere of flowing steam for 1 hour. The method is adopted from that of Roahen and Sommer (12).

Two 10-g. portions of each sample of cheese were added to separate 100 ml. quantities of sucrose-cream mixture. To facilitate homogeniety, the cheese and warmed sucrose-cream were ground together in a mortar. Immediately thereafter, one of this pair of bottles was held in a boiling water bath for 15 minutes to destroy any lipase present. Both bottles were then placed in a water bath and held for 12 days at 98° F. All samples were shaken vigorously daily for the first 6 days.

The changes in the acidities of the mixtures were determined by direct titration on a portion of the cheese and substrate as well as by determining the acidity volatile by steam distillation.

The direct titration was carried out by weighing out 20 g. of cheese and substrate, diluting with 20 ml. of distilled water, heating for 1 minute in a boiling water bath and then titrating against 0.1N NaOH solution with 0.5 ml. of 1% phenolphthalein solution.

In the steam distillation, distilled water was used as a source of steam. The apparatus was cleaned by passing steam through the still-head and condenser until 150 ml. of distillate was collected, prior to each determination. Twenty grams of cheese and substrate was adjusted to approximately pH 2 with 10% (by volume) H_2SO_4 solution after which distillation was continued until 100 ml. of distillate had been collected. The distillate was then titrated against 0.1N NaOH with 0.5 ml. of phenolphthalein as indicator. The results are presented in Table 2.

TABLE 2.—PRODUCTION OF ACIDITY IN SUCROSE-CREAM BY NORMAL AND SLIGHT RANCID CHEESE AFTER 12 DAYS INCUBATION AT 37° C.

Sample*	pH after 12 days at 98° F.	pH to which adjusted before distillation	Titration of 100 ml. of distillate	Direct titration of 20 g. of cheese and substrate
1 A	—	—	—	14.03
1 B	—	—	—	6.15
2 A	5.02	1.9	3.07	14.76
2 B	5.7	1.9	1.45	6.15
3 A	5.20	1.75	2.98	12.67
3 B	5.75	1.80	1.50	6.24
4 A	4.95	2.1	2.60	12.26
4 B	5.65	2.0	1.45	5.99
5 A	5.20	2.1	3.03	14.17
5 B	5.82	2.0	1.50	6.42
6 A	5.20	2.0	3.10	13.30
6 B	5.95	1.8	1.50	5.40

* A samples unboiled; B samples boiled. Samples 1, 2 and 3 first grade flavour; samples 4, 5 and 6 slight rancid flavour.

The values presented in Table 2 demonstrate clearly that lipolysis as indicated by the acidities produced in sucrose-cream mixtures was certainly no greater in rancid than in normal flavoured cheese. The results as shown by changes in pH, acids volatile by steam as well as the values obtained by determining the acidity of the cheese and substrate, are all in accord.

DISCUSSION

Two causes have been advanced as possible agents producing rancidity in cheese. The present study has been planned to learn whether normal and slight rancid cheeses would display different lipolytic activities when incubated in a suitable substrate. The results indicate that lipolytic activity is no greater in samples displaying typical slight rancid flavour than in those of normal, first grade flavour.

The treatment which the substrate received (low pressure homogenization) was such as to render it readily attachable by lipase enzyme. Lane and Hammer (9, 10) found that low homogenization pressures were effective in producing rancidity and increased volatile acid production in blue cheese and cheddar cheese. Assuming, therefore, that in this experiment the butterfat was as readily hydrolysed by the lipase in the normal as in the slight rancid cheese, the conclusion is apparent that the two types of cheese contained relatively the same quantity of lipolytic agent.

Krukovsky and Herrington (8) have advanced an "activation" theory to explain the increased rate of lipase action which is brought about in milk by warming and cooling. Hlynka, Hood and Gibson (5) have found that agitation of milk at about 86° F. accelerates the development of rancidity in cheddar cheese. The latter group have also shown (6) that

this agitation results in a greater degree of fat dispersion in the milk. Their contention that the term "activation" should apply more particularly to the substrate than to the enzyme would seem to be valid.

The results reported in the present study appear to suggest that the treatment which the substrate (i.e. the fat globules) receives is the determining factor in the development of this flavour defect, rather than the concentration of lipase. Any and all factors which operate to de-surface the fat globules or increase their state of dispersion, will require study if a solution of this problem is to be achieved.

SUMMARY

Lipase action has been suspected as an agency causing cheese to develop slight rancid and rancid flavours. An experiment is reported in which samples of normal and defective cheeses were incubated in a sucrose-cream substrate. The results indicate that the concentration of lipase was approximately equal in these two types of cheese.

ACKNOWLEDGMENTS

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EFFECT OF CERTAIN METHODS OF HANDLING UPON THE BACTERIAL CONTENT OF DIRTY EGGS[1]

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During the summer of 1944, and again to a lesser extent during 1945, an occasional egg broken in plants breaking eggs for the Special Products Board for subsequent drying was found to contain enormous numbers of bacteria while showing no evidence of abnormality in appearance or odour. The organisms isolated were common soil and water types which presumably had gained entrance to the egg subsequent to its being laid (8).

While the studies of Haines (3) indicate that a good quality, fresh, unwashed egg is extraordinarily resistant to bacterial penetration, the consensus of opinion is that dirty eggs, especially if washed prior to storage, are much more likely to become infected (5, 6, 9, 10). Since the washing of dirty eggs on the farm offered a possible explanation for the high count eggs the authors has encountered, arrangements were made with the Poultry Division, Central Experimental Farm, to supply naturally dirty eggs the same day they were gathered. These were then subjected to the treatments outlined below, in the hope that some light would be thrown upon the question.

EXPERIMENTAL

Three times a week, commencing May 16, 1945, one dozen "dirties" were brought to the laboratory. During the first half of these studies, alternate dozens were placed in the 37° C. incubator for 1 hour to warm up before further treatment (to facilitate bacterial penetration of the shell), while the remainder were not warmed up. From each 12 eggs, 6 were left unwashed as controls; the other 6 were washed with a wet cloth, no detergent being used. The cloth was dipped in an enamel measure containing 1500 ml. of water at around 20° C. (68° F.) before wiping the dirt, almost entirely fecal matter, from the shells. Each succeeding egg was washed in the same water, which became progressively dirtier. Without any attempt at drying, the washed eggs were returned to their cartons and, along with the controls, stored at 14° C. (58° F.) with a relative humidity of around 50%. Three weeks later they were removed; the control eggs were washed in the same way (to minimize contamination of contents during their removal from the shells), and allowed to dry. Each egg was then immersed in a 1/500 solution of Roccal at around 40° C. (104° F.) for a minute or two prior to being opened.

Using sterile forceps, an area of shell large enough to allow the egress of the contents was removed from the blunt end of the egg. The contents were then transferred to a sterile 4 oz. screw cap jar, examined for fluorescence under an EH4 mercury arc lamp equipped with a Corning No. 587 filter (8), and checked for odour and appearance. They were then rendered as homogeneous as possible[4] by means of a mechanical agitator equipped

[1] Contribution No. 207 (Journal Series) from the Division of Bacteriology and Dairy Research. Issued as paper No. 148 of The Canadian Committee on Food Preservation.
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[3] Dairy Specialist.
[4] Unpublished data indicate the difficulty of obtaining a uniform dispersion of bacteria in eggs by the methods previously employed—beating with a spoon or shaking in a jar.

with two sharp blades tilted at about a 30° angle. Plates were poured on appropriate dilutions with tryptone glucose extract milk agar (7) for total count and incubated at 30° C. for 3 days; 1 ml. portions were also plated on violet red bile agar and incubated for 20 to 24 hours at 37° C. Where the bacterial content was high, cultures of the predominant type were isolated for identification and further study.

By the time the first 4 dozen had been analysed, it became evident that very few eggs contained more than an occasional organism. (The highest count noted was 17 per ml.). Since the contamination on the shells of the eggs was almost entirely of a fecal nature, while the organisms isolated from high count eggs have been chiefly soil and water types, it was felt desirable to increase the opportunities for contamination with these types. For this purpose, surface soil was collected from in front of one of the colony houses in use in 1944; this was moistened sufficiently to make a paste, and each egg dipped into it so that approximately 25% of the shell was soiled. The entire dozen eggs were then placed in the 37° C. incubator for one hour, when the washing of one-half the lot was carried out as described.

RESULTS AND DISCUSSION

The distribution of bacteria counts and other relevant data from the variously handled lots of eggs are shown in Table 1.

The most surprising feature is the low percentage of eggs showing any appreciable number of bacteria. Bryant and Sharp (1), examining the whites and yolks of naturally dirtied eggs which had been washed, then held at room temperature for 30 days, found all the way up to 100% containing over 100 organisms per ml.; yolks of unwashed controls were infected in 83% of the cases. (Unfortunately, these workers failed to indicate the magnitude of the counts obtained on infected eggs, so that comparisons on this point cannot be made.) This is the more surprising because our treatments of the eggs, including warming before washing, are believed to be more favourable to bacterial penetration than were the methods they employed.

In our studies, supplementary soiling of the shells with mud resulted in a significant increase in the number of eggs carrying more than 250 bacteria per ml., as well as in the average count per egg. However, the latter figures are greatly influenced by a single egg which gave a count of 62,000,000 per ml.

Washing in itself had much less effect upon the number of infected eggs than had been anticipated. The number of washed eggs with counts in excess of 250 per ml. was identical with that of the unwashed controls (7 in each). However, 4 of the 7 washed eggs gave counts of 2,100,000 per ml. or higher (maximum 62,000,000), while only 1 of the controls showed a count (4,900,000) in excess of 40,000 per ml. (Table 2). The number of bacteria which would be contributed to melange by the washed eggs is therefore significantly higher than for the controls, as indicated by the average counts; 643,778 for 130 washed, and 38,638 for 129 control eggs.

Warming prior to washing also influenced the number of infected eggs less than was expected. In the case of the control eggs which did not

TABLE 1.—DISTRIBUTION OF BACTERIA COUNTS FROM 259 DIRTY EGGS WASHED BEFORE OR AFTER STORAGE FOR 3 WEEKS AT 14° C. (58° F.)

Controls	Count per ml.														
	No. of eggs	Median count	Average count	< 1	1-10	11-50	51-250	251-1000	1001-5000	5001-25,000	25,001-100,000	100,001-500,000	500,001-2,500,000	2,500,001-10,000,000	> 10,000,000
Washed after storage															
A. Fecal contamination on shell															
1. Not warmed before storage	29	< 1	1,380	17	11						1				
2. Warmed before storage	34	< 1	1	20	13	1									
B. Feces and mud on shell															
Warmed before storage	66	2	74,913	8	15	3	4	2		2	1			1	
Washed before storage															
A. Fecal contamination on shell															
1. Not warmed before storage	30	< 1	7,668	16	12	1						1			
2. Warmed before storage	36	< 1	102,786	23	9	1	2							1	
B. Feces and mud on shell															
Warmed before storage	64	1	1,255,825	14	10	2	2	1		2			1		2

TABLE 2.—DATA CONCERNING EGGS SHOWING COUNTS ABOVE 5,000 PER ML.

Egg No.	Bacteria count per ml.	Coliform organisms per ml.	Fluorescense of egg	Predominant organism isolated	Large pores in shell	Treatment of egg: Washed before storage	Washed after storage	Warmed before storage	Not warmed before storage	Soiled with feces	Soiled with mud and feces
229	5,600	< 1	–	Micrococcus			x	x			x
368	6,800	< 1	–			x		x			x
245	8,000	< 1	–				x	x			x
424	9,400	< 1	–		x	x		x			x
407	29,000	< 1	–	Escherichia	x		x	x			x
145	40,000	< 1	–	Flavobacterium	x		x		x	x	
186	230,000	< 1	–	Flavobacterium		x			x	x	
302	2,100,000	< 1	+++	Bacterium	x	x		x			x
170	3,700,000	60	–	Flavobacterium		x		x		x	
249	4,900,000	< 1	–	Pseudomonas	x		x	x			x
244	15,000,000	< 1	–	Flavobacterium	x	x		x			x
282	62,000,000	< 1	+++	Bacterium	x	x		x			x

receive a supplementary soiling with mud, the warmed eggs actually showed up better than the unwarmed. However, average counts per ml. were significantly higher for the entire lot of warmed eggs, being 441,013 for the latter (200 eggs) and only 4,577 for the 59 unwarmed eggs.

Since eggs with large pores in the shell might be expected to become infected more readily (1, 2), the presence of such pores, as indicated by the escape of air bubbles when the cold egg was immersed in warm Roccal solution, was noted when observed. While few eggs with high counts failed to show large pores, a surprising number with large pores remained virtually free from bacteria.

Examination under ultra-violet light again proved to be of limited value in the detection of high count eggs. As will be seen from Table 2, only 2 eggs showed fluorescence. Both of these gave counts in excess of 2,000,000 per ml. As in our previous studies (8), there was no close correlation between fluorescence in the egg and the presence of organisms of the genus *Pseudomonas*. Fluorescence was not noted in any of the remaining 257 eggs examined.

A word of explanation is necessary concerning Egg No. 407 in which organisms of the genus *Escherichia* were predominant, although no coliform organisms showed up on the violet red bile agar at the initial examination. The tryptone glucose agar plates poured from 1 ml. of this egg showed over 300 mould colonies; one of the moulds isolated was tested out in another connection for its antibiotic potency, and was found to exert a definite inhibitory action on *E. coli*. This may explain the inability of the coliform organisms to develop sufficiently on the violet red bile medium to be recognized after 20 to 24 hours incubation.

In view of the fact that all eggs as received were found to be smeared with fecal matter, it was surprising to find coliform organisms present in only two other eggs. One of these had been warmed and washed before

storage; it gave a count of 60 coliforms per ml. along with a total count of 3,700,000 per ml. The other, not washed until after storage, gave a count of 2 per ml. with a total count of 6 per ml.

In view of the apparently greater resistance to infection shown by the eggs in these studies, it was felt that some other factor might be involved. Since the eggs studied all came from the Central Experimental Farm flock where the hens receive a ration which is regarded as nutritionally adequate, it seemed possible that this might be a factor inasmuch as many farm flocks may not receive as adequate a ration. This point may warrant further investigation.

SUMMARY

A surprisingly small percentage of 259 new-laid dirty eggs contained appreciable numbers of bacteria after being stored at 14° C. (58° F.) for 3 weeks.

Washing with a wet cloth before storage did not increase the number of infected eggs, but the average count of such eggs was appreciably higher than that of eggs washed shortly before analysis.

Warming the egg prior to washing also influenced the number of infected eggs less than was expected, although the average count was again higher than for the unwarmed eggs.

Supplementary soiling with mud of eggs naturally soiled with fecal matter increased the number of infected eggs as well as the average count. Coliform organisms were rarely encountered.

ACKNOWLEDGMENTS

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THE RELATIVE ANTIRACHITIC POTENCY OF IRRADIATED ERGOSTEROL (D_2) AND IRRADIATED 7-DEHYDRO-CHOLESTEROL (D_3) FOR GROWING PIGS[1]

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It is commonly believed by nutritionists and feeders that swine require a dietary source of vitamin D or its equivalent in ultra-violet irradiation. Complete absence of some antirachitic agent presumably leads to faulty and/or slow bone formation demonstrable experimentally by means of size measurements, by line test, or by bone ash determinations. There is no question but that under some conditions of practical feeding and management, young pigs may become lame and clinically 'rachitic.' Furthermore, such conditions are reportedly prevented and, if not too advanced, cured by the feeding of some potent source of vitamin D.

Strangely enough, however, entirely satisfactory evidence concerning the minimum vitamin D requirements for swine is not to be found in the literature. Indeed the occurrence of clinical rickets appears to be highly variable among experimental animals confined to so called 'rachitic' diets.

One of the latest reports bearing on this question is that of Braude, Kon, and White (2) who found no rickets among pigs fed normal diets containing 0.5% P or over and a Ca : P ratio of 1.4 : 1. Similarly, Bethke *et al.* (1) found that within Ca : P ratios of 1 : 1 to 2 : 1 and with rations containing not less than 0.6% P, satisfactory growth and bone formation took place without vitamin D. Dunlop (4) concludes that diets providing 0.6% P and a Ca : P ratio of 0.75 : 1.0 do not need vitamin D supplementation. It is interesting to note the finding of Johnson and Palmer (6) that white pigs become rachitic more slowly than dark-skinned hogs because of greater storage of vitamin D prior to their experiments. This difference in skin colour was reported by Marek *et al* (cited by Braude *et al.* (2)) who also give 1.85 gms. P per 10 kgms. body weight and a Ca : P ratio of 2.2 : 1 as the minimum of P for white pigs where no vitamin D is furnished. On this basis, and figuring that a 50-pound pig requires 2.7 pounds air-dry feed, the daily P need would be 4.2 gms. or equivalent to 0.3% of the ration.

Against these findings must be set numerous reports in which rickets was found among pigs, in some cases even with apparently adequate Ca and P ratios and intakes. For example Braude *et al.* (2) found that the introduction of brewers' dried yeast into the ration brought on rickets which was not cured or prevented by extra Ca or P but responded to small doses of cod-liver oil (about 2 gm. cod-liver oil per pig per day, apparently furnishing some 200 i.u. vitamin D per pig per day). Senior (7) found rickets among young weaned pigs never exposed to sunlight or given vitamin D.[4] This diet carried Ca/P ratios ranging from 0.76 : 1 to 1.53 : 1 and with P as 0.78% of the ration. Their dams had had access to sunlight during pregnancy and lactation. The development of the rachitic condition was prevented by additions of (about) 1% of cod-liver oil to the diet.

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It is difficult to reconcile these contradictory findings. Apparently in the absence of known sources of vitamin D, growing pigs may or may not develop a rachitic condition. Rickets appears to be a more certain result when the intake of P or of Ca falls below certain minimum values, or when the Ca/P ratio deviates widely from 1 : 1.

One factor which may be involved is growth rate. The requirements for Ca and P are obviously closely associated with the live weight gains being made, and if, through restriction of the intake of these minerals, the pigs reduce their rate of gain sufficiently, then no rickets is to be expected. It may be pointed out that 'normal' gains as frequently reported imply gains comparable to some standard. Unless the standard used is stated, the results cannot be adequately judged. In the majority of reports in which growth rates are cited, they are below the 'expected gains' set out in the Recommended Nutrient Allowances for Swine published by the Committee on Animal Nutrition of the U.S. National Research Council (9).

In view of the increasing use in farm rations of synthetic vitamin D, the question of the requirements of swine for this vitamin has again arisen, together with the added problem of whether or not the irradiation products of different sterols, particularly of ergosterol (D_2) and 7-dehydrocholesterol (D_3), are of equal effective antirachitic potency for this species.

Accordingly in 1943 a study was undertaken with the specific object of comparing the effectiveness of vitamin D_2 and D_3 in preventing rickets in pigs placed on rachitic diets at a weaning age of about 56 days. Two tests have been completed and are hereinafter reported.

EXPERIMENTAL

Test I

The prophylactic method of assay was employed, using percentage ash in moisture-fat-free bone as the criterion of the antirachitic value of the vitamin D given.

The reason for using this method, in spite of the somewhat larger numbers of animals required, was that it avoids a preliminary depletion period and the problems of establishing and identifying clinically equal degrees of rickets, procedures for which are at present not available for swine.

Thirty-two Yorkshire pigs, weaned and started on test at 56 days of age were alloted to 8 lots of 4 pigs each. The allotment was at random subject to the restriction of equal numbers of each sex in each lot of 4.

The pigs during the assay period were penned and fed individually. They were weighed and feed checked weekly.

The basal feed mixtures for all pigs consisted of:

Ground wheat	43.5 lb.
Ground oats	45.0 lb.
Dried liver and lung meal	7.0 lb.
Calcium carbonate	4.0 lb.
Salt	.5 lb.
Carotene	150.0 mg.
Vitamin B complex: Thiamin 1 part, Riboflavin 2 parts, Niacin 4 parts	315.0 mg.

Based on average samples of the above feeds this mixture carried about 15% protein, 1.66% Ca, and 0.43% P.

Experimental evidence indicates that while the most usually occurring swine rickets is of the low Ca type, a ration with between 0.30 and 0.50% P with a Ca/P ratio of about 4 may be expected in the absence of vitamin D to produce a subnormal bone ash; and that at these same intakes, normal bone ash will be found if adequate vitamin D is included in the ration.

The general design of the test is indicated by Figure 1 showing the allotment of the pigs to the several groups.

FIGURE 1.—ALLOTMENT PLAN OF VITAMIN D TEST
(Total pigs, 32)

Vitamin D per day/pig	Form of Vitamin D	
	Ergosterol (D_2)	7-dehydro-cholesterol (D_3)
Check	4 pigs	
10 i.u.		4 pigs
20 i.u.	4 pigs	
40 i.u.		4 pigs

Results of Test I

It was intended that the pigs should be fed for a period of 42 days after which they would be killed, the long bones (ulna and radius) of the front legs removed for line test and the metacarpals examined for bone ash determination. At the end of the first 6 weeks, however, there was no clinical evidence of rickets; and 3 male pigs killed[4] showed bone ash values from 62.7% to 63.4%. The feeding period was therefore continued for a second 6 weeks after which 6 additional pigs were killed. These showed bone ash values ranging from 58.5% to 61.9%; and line tests indicated normal bone formation. The remaining 19 pigs were continued on feed for a further 4 weeks after which they were slaughtered. Bone ash values ranged from 58.5% to 63.6%. Line tests showed normal calcification. No sex differences were found.

Two control pigs killed at the start of the test had bone ash of 59.1%. The average bone ash values for the groups are shown in Table 1.

TABLE 1. AVERAGE % BONE ASH VALUES

Vitamin level	Form of vitamins	
	D_2	D_3
Check	61.9	61.9
10 i.u./day	61.2	61.7
20 i.u./day	61.4	60.2
40 i.u./day	59.8	58.5

[4] We are indebted to Canada Packers for killing facilities and for absorbing losses due to special cutting for all hogs in these studies.

It is obvious from the figures in Table 1 that there was no rickets in any of the groups, which of course precludes any conclusion as to the relative potency of ergosterol vs. 7-dehydrocholesterol as sources of the antirachitic vitamin. Actually the standard deviation of the % ash values was 1.4, necessitating a difference of 2.23 units of per cent between groups of 4 pigs to cover variations not related to experimental treatments. Between D_2 and D_3 there was no case of a significant difference; and the lowest values for the highest daily intakes of the vitamin, though in one case statistically significant, are biologically contrary to expectation.

The most probable explanation of the failure of rickets development was the slow rate of growth shown by all pigs. These are summarized in Table 2.

TABLE 2.—AVERAGE DAILY GAIN AND FEED INTAKE OF PIGS

Group	Initial weight	6 Weeks			16 Weeks		
		Gain	Feed	F/G	Gain	Feed	F/G
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Check	26	0.69	2.6	3.8	1.12	4.4	3.9
10 i.u.	30	.46	2.2	4.9	0.92	3.8	4.2
20 i.u.	30	.59	2.5	4 2	94	8	4.0
40 i.u.	24	52	2.1	4 0	.86	3.5	[illegible].1
D_2 all lots	27	0 48	2 1	4.4	0.87	3.5	4.1
D_3 all lots	28	55	2 3	4 2	95	3.9	4.2

The average gains for all pigs were 0.48, and 0.90 lb. per day during the 6- and 16-week periods, respectively. Normal gains should be nearly double these figures.

The failure of the pigs to gain normally might be charged to inadequate levels of vitamin D were it not for the fact that there was no evidence of increased gain with increasing level of vitamin D intake. Feed consumption was low and the feed required for one pound gain was higher than normal. The vitamin A intake was 50% above the requirements set out in the feeding standard proposed by the U.S. National Research Council Committee on Animal Nutrition (9).

These facts lead to the belief that the limiting factor in this diet for the growth of pigs was protein. Restriction in amount or in quality of protein normally results in low feed intake, poor feed utilization, and in slow gains. In order to prepare a ration as low in P as possible, the usual protein supplements were of necessity avoided Liver and lung meal was chosen as one of the few high protein feeds with low P content.

Conclusions from Test I

Obviously this trial yields no data upon which conclusions relative to the usefulness of vitamin D_2 compared to D_3 as antirachitic agents in swine rations can be made. It seems evident that on rations which do not permit more rapid growth than observed in this test, rickets may not develop even in the absence of known sources of antirachitic substances in the diet and with the Ca/P ratios as high as 4 : 1.

Test II

Because of the difficulties experienced in the previous test with a suitable source of protein in preparing low P diets for swine, it was decided to employ a low Ca, high P diet in this trial. Senior (8) has reported that neither ratio of Ca to P, nor level of intake of these elements will eliminate the need for vitamin D in the swine ration. Rickets was produced in his test on diets supplying 0.6% P and 0.47% Ca. A diet containing this quantity of P will permit the use of foods normally found in swine rations which are expected to produce normal growth.

Thirty-two Yorkshire pigs weaned at 52 to 56 days of age and started on test at initial weights ranging from 17 to 28 lb. at ages of about 56 days were allotted to 8 groups of 4 pigs each. The allotment was random, subject to the restriction of equal sexes in each group.

Each group of 4 pigs was penned together and feed records made for the groups only. Feed was allowed to limit of appetite. It was prepared for feeding by pouring over the dry meal allowance, in the trough, water equal to about 3 times the weight of dry meal. The length of the feeding period was 6 weeks for all pigs, at which time one-half were killed for bone ash assay. The remaining 16 pigs were carried for a further period of 10 weeks.

The feed mixture finally used was made up as follows:

Ground barley	79.5 lb.
Linseed oilmeal	5.0 lb.
Soybean oilmeal	5.0 lb.
Defatted wheat germ	5.0 lb.
Fish meal	5.0 lb.
Salt	0.5 lb.

To each 100 pounds of the above was added:—

Ferrous sulphate	7 grams
Carotene	50 milligrams
Riboflavin	10 milligrams
Pantothenic acid	100 milligrams

Based on average samples this combination carried approximately 18% of crude protein, 0.57% of P, and 0.28% of Ca.

The allotment plan and the levels of vitamin D supplements were identical with that shown in Figure 1 for Test I.

Examination of the complete data of this trial reveals no difference in gains between control lots and any of the 3 levels of vitamin D, and obviously therefore, none between the two forms of vitamin D used.

A comparison of the average gains of all pigs as compared to the Macdonald College Standard (3) is interesting and perhaps significant in this respect.

In interpreting the curves in Figure 2 it is to be noted that the pigs which were killed after the first 6 weeks were the largest pigs in each group. These were chosen deliberately to see whether or not the most rapidly growing animals had become rachitic.

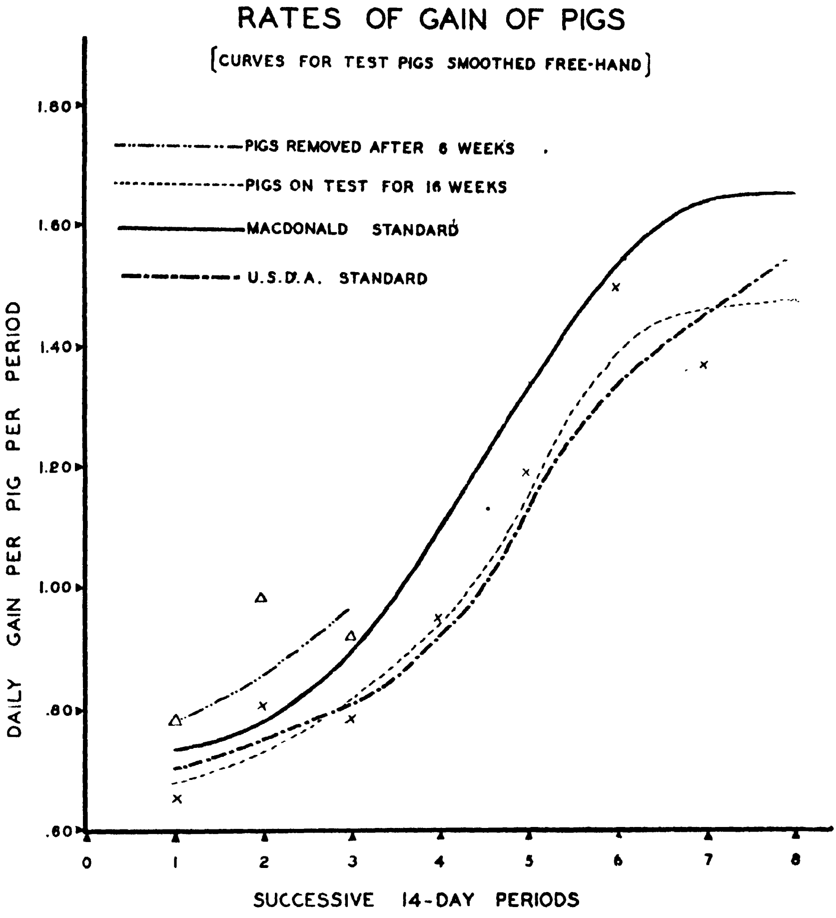

FIGURE 2. Rates of gain of pigs.

The curve of daily gain for those pigs which remained on test for 16 weeks was below the Macdonald College Standard but follows with surprisingly good fit, one calculated from the growth curves reported by the United States Department of Agriculture (5). If the gains of the faster growing pigs from this test are averaged with those of the slower half (for the first 6 weeks) their mean gains are almost exactly those expected on the basis of the Macdonald Normal Rate of Gain Curve.

The mean daily gains of all pigs for the two weeks during which they became 50 pounds in weight was 0.94 pounds which may be compared with expected gains, of 50-pound pigs, of 0.90 pounds according to the Standard of the Committee on Animal Nutrition of the United States National Research Council.

In so far as rickets is concerned, it failed to develop in a single pig. In Table 3 are given the mean gains and bone ash values obtained from this test.

TABLE 3.—AVERAGE GAINS AND BONE ASH VALUES ACCORDING TO SOURCE AND AMOUNT OF VITAMIN D FED

Dose level	All pigs—First 6 weeks				Pigs remaining on test 16 weeks			
	Irradiated Ergosterol (D_2)		Irradiated 7-Dehydro-cholesterol (D_3)		Irradiated Ergosterol (D_2)		Irradiated 7-Dehydro-cholesterol (D_3)	
	Gain 6 wk.	Bone ash	Gain 6 wk.	Bone ash	Gain 16 wk.	Bone ash	Gain 16 wk.	Bone ash
	lb.	%	lb.	%	lb.	%	lb.	%
Check	34	57	34	58	121	58	121	59
10 i.u./day	39	57	32	57	137	57	107	58
20 i.u./day	37	59	30	57	157†	57	101	58
40 i.u./day	35	56	38	59	120	55	132	54
Mean gains, all levels of Vitamin D	37	57	33	58	134	56	113	57
Normal gain, Macdonald College Standard	34 lb.				136 lb.			

* Average of 2 pigs per lot killed after 6 wk. feeding. Based on moisture-fat-free metatarsals.
† One pig only. Mate died from causes not related to test.

Chick Assay in Connection with Test II

In view of the complete absence of rickets, it was thought desirable to examine, as a possible source of vitamin D, the fish meal used, since it contained 16% fat (ether extract). Accordingly an assay[5] was arranged in which 4 groups of 20 chicks each were fed on a ration composed of:—

Yellow corn	58 lb.
Wheat middlings	25 lb.
Fish meal	12 lb.
Yeast	2 lb.
Precipitated tricalcium phosphate	2 lb.
Salt	1 lb.
$MnSO_4 \cdot 4H_2O$	10 grams

The fish meal in the above mixture was prepared as follows:—

Group	Extracted fish meal	Unextracted fish meal	Potential A.O.A.C. Units D/lb. ration[6]
	%	%	
Lot I (control)	100.0	0.0	0
Lot II	97.5	2.5	11
Lot III	95.0	5.0	22
Lot IV	90.0	10.0	44

[5] The co-operation of the Department of Poultry Husbandry is gladly acknowledged in this assay.
[6] The proportions of extracted and unextracted fish meal were such that on an assumed vitamin D potency of 50 A.O.A.C. units per gram for the oil in the fish meal, the diet of Lot IV would carry about 44 A.O.A.C. units of D per pound of ration as fed.

The chicks were confined to the test diets for 21 days, after which bone ash values of the leg bones were determined. The results were as follows:—

Group	Ash of Moisture-fat-free bone
	%
Lot I (control)	32.2
Lot II	33 4
Lot III	32.1
Lot IV	32.1
Normal	45 0

These data fail to indicate any measurable antirachitic potency of the fish meal used. Unless the fish fat contained principally D_2, which seems unlikely, it could be presumed that the fish meal was devoid of substances antirachitic for pigs.

DISCUSSION

These tests offer no basis for a comparison of the antirachitic potency for swine of vitamin D_2 or D_3. Indeed it would seem that the need of young growing pigs, from weaning time to weights of 175 pounds, raised entirely indoors during winter, is less than has been commonly believed. The pigs were from dams that received daily liberal amounts (8cc. of 2,000 A – 400 D) of feeding fish oil during pregnancy and lactation. During lactation (56 days) the fish oil allowance was put into the sows' feed troughs once daily. The litters had access to this feed and undoubtedly ate varying amounts of it. If they obtained enough of the vitamin D to prevent rickets during the next 16 weeks, then the storage of this vitamin in the body is more extensive than was found by Senior (7). Our results in this respect, however, are in agreement with the findings of Braude *et al.* (2) in so far as any need for vitamin D to prevent rickets is concerned.

It is to be recognized that in neither of these trials did the pigs gain as rapidly as called for by our own (Macdonald) standard. In the first trial this, we believe, can be accounted for by poor quality protein. In the second test it will be remembered that after 6 weeks, 2 pigs in each group of 4 pigs, were removed for determination of bone ash. The most rapidly growing pigs were deliberately chosen, thus leaving the slower growing pigs for the balance of the trial. The average gains, using all pigs up to 6 weeks, were normal according to the Macdonald College Standard (see Figure 2), and since the trend of gains of the pigs left on test parallels that of our standard it seems unlikely that their somewhat (0.15 lb. per day) slower growth rate was traceable to vitamin D deficiency. In any case it cannot be assumed that the failure of rickets was due to slow growth.

CONCLUSIONS

1. These tests yield no data on which to judge the relative antirachitic effectiveness of irradiated ergosterol (D_2) and irradiated 7-dehydrocholesterol (D_3) for young growing pigs.

2. Weaned at 8 weeks from mothers, who during pregnancy and lactation have received daily about 15,000 i.u. vitamin A and 3,000 i.u. vitamin D, young pigs confined indoors appear to have a considerably lower vitamin D requirement than present standards call for if:

(1) their diets contain at least 0.57% P;

(2) the Ca/P ratio is not wider than 0.5 : 1;

(3) bone ash values of the order of 57%, and normal trabecula, are taken as indicating normal bone metabolism.

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TESTING WHEAT SEEDLINGS FOR RESISTANCE TO HELMINTHOSPORIUM SATIVUM[1]

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INTRODUCTION

In Western Canada, plant breeders have made great advances in developing better cereal varieties, especially wheats resistant to stem rust. Occasionally a breeding program is well underway when the appearance of some unexpected disease may cause serious damage in the nursery and necessitate a change in plans. Sporadic infestations by common root rot fungi, notably *Helminthosporium sativum* P. K. & B. and *Fusarium* spp., in plant-breeding nurseries have been brought to the attention of pathologists from time to time. Studies on root rots, including varietal resistance, have been conducted for many years. It is generally agreed that the organisms mentioned above are usually associated with all outbreaks of common root rot and their pathogenicity can be readily demonstrated. Nevertheless the etiology of root diseases is complex, and the role of other fungi as well as the influence of the environment must not be overlooked. A step forward, however, will have been made if reliable and quick methods can be developed to analyse the reactions of a large number of varieties and lines to the well-known pathogens. This investigation, therefore, was confined almost entirely to the reaction of wheat seedlings to inoculation with *H. sativum;* in addition, strict attention was given to ways and means by which time and space might be conserved.

The plant breeder must finally test his material in plot and field to determine vigour, yield, and general quality. Such tests over a period of years and in many districts soon eliminate the weak lines. Presumably, selection has also eliminated those sorts most susceptible to root diseases. It would appear that something like this has functioned in the development of our better wheat varieties, for on the whole they have been vigorous and high yielding. However, the sporadic occurrence of root diseases as well as the possible occurrence of physiologic races makes this procedure very hazardous. A better knowledge of root diseases obtained through improved techniques should greatly reduce the trial and error effort.

The root rots were not well understood when expansive plant breeding programs were commenced in Western Canada about 1925. Three types of root disease were then under study. Investigations on resistance included inoculation tests in the greenhouse and field, the establishment or attempted establishment of root disease gardens by repeated soil inoculations, and observations of natural infections in comparative trials. Most of these studies gave fairly good comparative data but they all failed to provide advance information to the plant breeder. Such studies added little to what the breeder would obtain in the course of his ordinary field

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experiments. Some of the methods used and results obtained in Western Canada have been reported by Greaney, Machacek, and Johnston (2) and Tyner and Broadfoot (6). Studies on varietal resistance to common root rot have been conducted in this laboratory for many years. Some of the earlier tests were made by Mr. G. A. Scott while in later years the investigations were continued by Dr. B. J. Sallans. Rather extensive greenhouse and field experiments were reported in 1926 (4) and 1927 (5).

This and subsequent work as well as co-operate studies with Dr. J. B. Harrington at the University of Saskatchewan impressed upon us the necessity of more investigations on techniques. Those who have studied root diseases have noticed and reported from time to time upon tests dealing with varietal differences. The early work in this connection was reviewed by Christensen (1) who also gave the results of his extensive experiments with wheat varieties. Although all of this research has been valuable and helpful to the plant breeder, there still exists a great need for simple methods which would enable him to assess parental material and analyse resultant lines.

MATERIAL AND METHODS

The common root rot pathogen *Helminthosporium sativum* was used in most of the tests although a few trials were run with *Fusarium culmorum* (W. G. Sm.) Sacc. Both fungi has been in the laboratory stock for some time, but only freshly transferred cultures were used in these experiments. Many new isolates of *H. sativum* were made in 1944, and some of these were compared for virulence. In the preliminary tests, seed of the ordinary wheat varieties was used while later, various species, varieties, and lines were employed.

All of the first tests were made in test-tubes or culture-tubes and may be referred to as the test-tube test. Under certain conditions, *Petri* dishes fitted with a moistened filter paper were useful. In the test-tube method, the tube is fitted with a strip of blotter paper wide enough to fit nicely in the tube and of about the same length as the tube. The top portion of this strip is bent to form a shelf about two inches from the top of the tube (Figure 1). Water is added to the level of this shelf. In handling a large number of tubes, which are first placed in racks, it was found most convenient to fill all tubes to the top; then with a small pipette attached to a suction-pump; the excess water is drawn off and the shelf properly adjusted. The racks are now ready for seeding. The seeds are inoculated with a conidial suspension, usually from a 7-day old slant culture strained to remove large fragments. The suspension is poured over the seeds in a syracuse watch glass, then with forceps they are picked up and placed on the blotter shelf. The racks may then be placed in an incubator or kept in the laboratory, preferably the former. In 7 days, at 24° C., readings are made for degree of coleoptile lesioning, blighted seed, non-germination, etc. Generally, most attention was given to coleoptile lesions. Checks of uninoculated seed were run for viability, lesions, mouldiness, and so on.

In the Petri dish method, a larger number of seed may be used with greater economy of space; although this method cannot be employed if the seed shows a tendency to mould. A few mouldy kernels soon spoils a

test. This was one of the main reasons for development of the test-tube method wherein each seed is grown separately. Petri dishes are prepared by placing a filter paper to fit the bottom of the dish; 2 or 3 cc. of water are added at the start and another 2 cc. on the third day. The seeds are inoculated as described above and placed in the dish at the rate of 25 to a dish. This was the ordinary procedure, although in some tests the seeds were inoculated after being placed in the dish. Readings of symptoms as described above are usually possible on the fifth day.

EXPERIMENTAL RESULTS

Experiment 1

Over a period of about two years, the senior author conducted routine pathogenicity tests on several varieties of wheat. This was done with the object of studying methods. From this work, the test-tube procedure was devised. When this method was repeated from time to time, consistent varietal differences were noted in the replicates. After consultation with the junior author, the work was extended and additional attention paid to the subject of varietal resistance. In the preliminary tests the common varieties were tried using seed from the laboratory plots. The seed of Pentad, McMurachy's selection, Pelissier, and Mindum were several years old. From the Dominion Laboratory of Plant Pathology, Winnipeg, were obtained seed of Prelude, R.L. 25; H-44-24, R.L. 229; Thatcher (Double Cross), R.L. 1945; and a Marquis × Kanred hybrid. These latter sorts were studied because they represent parental material of some of the newer varieties. The seeds were inoculated with *H. sativum* as described above, and the racks were placed in an incubator at 24° for 7 days. In rating disease, most attention was given to the coleoptile lesions as they are the most distinctive symptom. For comparative purposes, the degree of infection was determined by deducting natural infections as shown by the checks from the total coleoptile lesions shown by the inoculated seed. A summary of the results of many replicates is given in Table 1.

TABLE 1.—A COMPARISON OF WHEAT VARIETIES IN THE SEEDLING STAGE FOR RESISTANCE TO *H. sativum*

Variety	Treatment	Total seeds	Seedlings			Infection
			Total	Clean	Coleoptile lesions	
				%	%	%
Marquis	Inoc.	216	178	86.4	14.6	9.6
	Check	216	179	95.0	5.0	—
Thatcher	Inoc.	216	202	73.8	26.2	18.6
	Check	216	210	92.4	7.6	—
Double cross	Inoc.	144	121	79.4	20.6	20.6*
Red Bobs	Inoc.	216	190	73.9	26.1	21.0
	Check	216	194	94.9	5.1	-
H-44-24	Inoc.	144	131	72.6	27.4	27.4*
Apex	Inoc.	216	175	67.5	32.5	30.5
	Check	216	186	98.0	2.0	—

* Check data were not available for these varieties.

TABLE 1.—A COMPARISON OF WHEAT VARIETIES IN THE SEEDLING STAGE FOR RESISTANCE TO *H. sativum*—*Continued*

Variety	Treatment	Total seeds	Seedlings			Infection
			Total	Clean	Coleoptile lesions	
				%	%	%
Marquis × Kanred	Inoc.	144	104	53.9	46.1	46.1*
Ceres	Inoc.	192	152	41.0	59.0	57.3
	Check	144	116	98.3	1.7	—
Renown	Inoc.	288	179	38.5	61.5	57.4
	Check	144	96	59.9	4.1	—
Prelude	Inoc.	144	77	38.9	61.1	61.1*
Reliance	Inoc.	288	173	34.6	65.4	63.7
	Check	144	114	98.3	1.7	—
Pelissier	Inoc.	228	108	12.9	87.1	78.2
	Check	144	89	91.1	8.9	—
McMurachy	Inoc.	216	121	12.3	87.7	78.7
	Check	216	165	91.0	9.0	—
Reward	Inoc.	228	160	9.3	90.7	79.5
	Check	144	107	88.8	11.2	—
Pentad	Inoc.	228	117	16.2	83.8	80.9
	Check	144	101	97.1	2.9	—
Regent	Inoc.	216	169	7.0	93.0	83.0
	Check	216	183	90.0	10.0	—
Mindum	Inoc.	228	104	9.6	90.4	88.3
	Check	144	95	97.9	2.1	—

* Check data were not available for these varieties.

Note.—The infection is the difference in per cent between lesioned seedlings of inoculated and check.

The results are considered indicative of possible trends but by no means final. Past experience with this type of infection had revealed its great sensitivity to its environment, with a subsequent variable expression of lesions. The rather consistent agreement between the many replicates, however, added greatly to the value of the ratings. Then again only seedlings were considered, and these were classed as having clean coleoptiles or coleoptiles with distinct lesions of the type caused by *H. sativum*. Some varieties showed a large number of blighted seed, obviously invaded and quickly killed. These and other signs and symptoms, although of some interpretive value, were not considered in the early trials. On the basis of the ratings in this experiment, Marquis was the most resistant variety. In most of the tests, it had shown not more than a moderate amount of infection. Thatcher was next to Marquis in resistance in these tests. On the whole, Thatcher was the most consistently resistant wheat studied. In the top group, it should be noticed, we have three well-known varieties that have shown, over a period of years, good all-round performance; namely, Marquis, Thatcher, and Red Bobs. Their resistance to *H. sativum* and

possibly other root pathogens might well explain their acceptance by farmers who must base their judgment mostly on yield and quality. We have no information on parental material of Red Bobs and Marquis except one small test with Red Fife in which it showed moderate to low susceptibility. In the Thatcher pedigree, there are Marquis, Kanred, and Iumillo wheats. The first two appear to have fair to good resistance as shown by seedling tests, while Iumillo was classed as poor in one trial.

When the new Canadian wheats are considered, Apex is the most resistant. Apex came from a cross between (H-44-24 × Double Cross) and Marquis. These parental lines all showed up well in this test. It should be mentioned that the Double Cross hybrid line used here certainly was of the same Thatcher origin and closely related to if not the same hybrid as used in the original Apex cross. The other two well-known Canadian varieties, Renown and Regent, showed little resistance to *H. sativum* and they both have Reward, a highly susceptible variety, in their pedigrees.

The two durum varieties, Pelissier and Mindum, were very susceptible; this is in agreement with general observations.

The quality of the seed is thought to be quite important in tests of this nature. There was considerable non-germination in some wheats, particularly with old seed. This factor, which was further aggravated by mouldiness in some and an increase in blighting when inoculated, made it difficult to assess this portion of the results. This, however, may be overcome by devising a disease rating formula.

Experiment 2

This test was run to compare some varieties having seed of uniform quality. Thatcher, Marquis, Apex, and Reward were grown in the greenhouse and examined at heading time for trueness to type by J. Whitehouse, Field Husbandry Department, University of Saskatchewan. The seed was of high viability. The inoculations and procedures were the same as in the above experiment with the disease rate being taken as the percentage of seedlings with coleoptile lesions. Checks were not used. As a rule, greenhouse seed is quite free of infections of the type studied here.

TABLE 2.—A COMPARISON OF WHEAT VARIETIES IN THE SEEDLING STAGE FOR RESISTANCE TO *H. sativum* USING GREENHOUSE GROWN SEED

Variety	No. of seed inoculated	Seedlings	
		Clean	Diseased
		%	%
Thatcher	100	76	24
Marquis	100	63	37
Apex	100	54	46
Reward	100	11	89

The results revealed the usual arrangement of these varieties, with Thatcher the most resistant, Reward the least, and Marquis and Apex intermediate.

Experiment 3

This experiment with three varieties will serve to show results with Petri dishes and also how a disease rating formula may be applied. As a rule, 25 seeds are sown to a dish after inoculation and each dish serves as a replicate. The material can usually be read on the fifth day, when the seedlings are classified and valued as follows: clean, 0; coleoptile lesions, lesions, trace 1, slight 2, moderate 3, and severe 4. The disease rate is derived by a formula originally used by McKinney (3), as follows:

$$\frac{\text{Sum of all numerical ratings}}{\text{Total number of seedlings with lesions} \times \text{maximum rate}} \times 100 = \text{Disease rate.}$$

Applying this to the first line of data in Table 3, we have:

$$\frac{5 + 20 + 9 + 8}{23 \times 4} \times 100 = 45.6$$

The results for this experiment are shown in Table 3.

TABLE 3.—A COMPARISON OF WHEAT VARIETIES IN THE SEEDLING STAGE FOR RESISTANCE TO *H. sativum* USING A PETRI DISH MOIST CHAMBER METHOD

Variety	Replicate	No. of seed	Clean seedlings	Coleoptile lesions				Disease rate	
				Trace	Slight	Moderate	Severe	Replicate	Average
Thatcher	1	25	3	5	10	3	2	45.6	
	2	25	2	7	5	4	6	55.2	
	3	25	1	8	11	0	3	45.6	48.4
	4	25	2	8	4	2	4	47.5	
Reward	1	25	0	6	3	8	6	65.2	
	2	25	0	4	4	2	9	71.0	
	3	25	0	3	8	5	3	60.5	60.6
	4	25	6	4	7	2	5	45.8	
Little Club	1	25	0	10	5	4	4	52.1	
	2	25	0	5	5	5	8	67.4	62.8
	3	25	1	5	3	7	8	66.6	
	4	25	1	7	3	4	9	63.5	

This method is quite satisfactory if rapidly spreading moulds do not appear. It has the advantage of using little space for large populations.

A disease rate based upon weighted degrees of lesions tends towards a fairer evaluation on border-line cases. It can, of course, be applied to the test-tube method as well.

The variety Little Club did not do well in this test although in other trials with different seed it proved fairly resistant. This variety is worthy of more attention from a root disease standpoint.

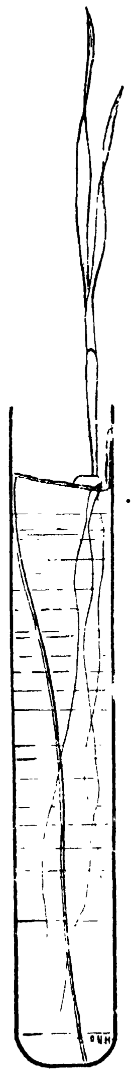

FIGURE 1. The test-tube method showing a wheat seedling after 7 days' growth at 24° C. The seed rests on a blotter paper strip which serves also as a wick. Shoot and root growth are readily observed.

DISCUSSION

It was not the main purpose of this study to delve into or review the work on the causes of resistance to this type of disease. The literature mentioned and our own work heretofore show quite definitely the existence of varietal differences to invasions by *H. sativum*. It appears that this pathogen is one and possibly the principal pathogen in causing common root rot of wheat in Western Canada. Therefore, tests with this fungus are of direct value in any wheat breeding program. As mentioned before, differences between varieties have been determined by many workers, but

usually these determinations are made from field or greenhouse tests, involving much time and labour. Frequently, the trials are made with varieties or lines which have already survived extensive field tests in the plant breeder's nursery, where the more susceptible or those of low root vigour presumably would be eliminated. Very often, therefore, the pathologist is studying lines which have been exposed to and have survived various root disease milieux. Great differences would not be expected in such material, and this appears to be the case in testing many of the new varieties. Such a procedure, although satisfactory for a long-time arduous program, certainly does not provide a quick and easy way of recognizing and classifying material suitable for parent stock. Investigations, therefore, must continue for reliable and rapid analytical methods by which large quantities of prospective parental stocks as well as new lines may be tested. It is encouraging to note in general that the results of our tests agree well with our field observations over the past few years, especially in regard to the resistance of Thatcher and the susceptibility of Reward.

The tests studied here appear to have some promise. On the whole the test-tube method is more reliable for the general run of seeds where moulds may be a disturbing factor. It is suitable for germination tests from which one can readily determine natural infections, mouldiness, and vigour; all of which is necessary information before one can evaulate inoculation results. The Petri dish method is certainly economical on space and with mould-free seed should be satisfactory. It is desirable to conduct all tests at a known suitable temperature such as 24° C. This angle, however, should be studied further. The same is true regarding whether the seedlings should be incubated in the dark or light. In so far as these factors were observed, there did not appear to be any great difference.

There seemed to be no doubt that seed to be tested should be of high viability and of good general quality. This is particularly true for the Petri dish method. In fact, it is our opinion that the seed of all material to be compared should preferably have been grown under the same conditions.

Besides the varieties mentioned above, numerous small tests both in tubes and plates were conducted with other varieties and cereals. Preliminary trials were also carried out on a large number of lines obtained from plant breeders. In many cases, distinct and consistent differences were noted. A few inoculations with *Fusarium culmorum* showed that it could be used in the methods outlined above. Tests were run with isolates of *H. sativum*, and although there did not appear to be sharp differences, there was sufficient variation to warrant additional observations.

It is our hope that rapid methods may help in analysing plant breeding material. Furthermore the test-tube method seems to have some value for germination tests, disease examination, and pathogenicity, vigour, and nutritional studies.

SUMMARY

1. The results of preliminary studies on rapid methods for testing wheat varieties for resistance in the seedling stage to infections by *H. sativum* are given.

2. Two methods were used. The first consists of test-tubes fitted with a strip of blotter paper folded to provide a shelf about 2 inches from the top of the tube. Water is added level with the shelf. The inoculated seeds are placed on the shelf. After 7 days of incubation, the infections are recorded. In the second method, Petri dishes fitted with moistened filter paper are employed. The inoculated seeds are laid in rows and incubated for 5 days.

3. The tests show that Marquis, Thatcher, Red Bobs, and Apex have more resistance than Mindum, Regent, Reward, Pelissier, and Renown. The trials were with seedlings only; and although possibly of value in analysing breeding material, any interpretation of the behaviour of a variety beyond the seedling stage must be made with caution.

ACKNOWLEDGMENT

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THE EFFECT OF FREEZING AND COLD STORAGE UPON THE BACTERIAL CONTENT OF EGG MELANGE[1]

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The effect of freezing and subsequent storage upon the bacterial content of egg melange has been studied by various workers. Stiles and Bates (16) reported a definite increase in count during the early part of the storage period; melange from strictly fresh eggs increased in count up to 3 months, then declined. Swenson and James (17) showed a drop in count from 150,000 to 60,000 per gram following freezing in dry ice and storage for 8 months at −20° C. (−4° F.). Nielsen and Garnatz (13) reported sharp reductions in counts of whole eggs containing 14% added salt after 41 days storage at −18° C. (−0.4° F.); yolks with 10% added sugar, on the other hand, showed an increase in the 20° C. count after 36 days, with a subsequent decline on further storage. Holtman (3) reported a 99% reduction in total numbers of bacteria and in most instances absence of coliform types after 7 to 9 months storage at −5° to 0° C. (23° to 32° F.) Schneiter, Bartram and Lepper (15) generally found a decrease in count on resampling after 60 hours in the freezer, but in one pack the count increased from 10,000 to 62,000 per gram. Lepper, Bartram and Hillig (11) also found an occasional sample with a higher count after freezing, although the count generally declined.

From the above review, it is difficult to decide just what effect freezing may be expected to have upon the bacterial content of whole eggs. The studies reported in this paper were initiated in the hope of providing a more definite answer.

EXPERIMENTAL

In the first series, sets of 4 samples of melange from freshly filled oblong metal moulds, lined with wax paper, were taken at intervals at a local breaking plant. The moulds were placed in a sharp freezer at approximately −19° C. (−2° F.); 2 days later the frozen blocks (6″ × 7″ × 24″) were bored with a sterilized 1″ auger at the center, near the end, and midway between the first two. A composite sample from the three borings was taken for analysis. Additional samples were taken from the same block after 1, 3 and 6 months storage at approximately −15° C. (5° F.). All samples were brought to the laboratory and analyzed with a minimum of delay. Except where specified, the methods used in official control of Canadian whole egg powder (6) were employed.

In the second series, 20 samples of melange were taken from freshly filled moulds of the same type and size at an Eastern Ontario breaking room, and analyzed at once in the plant laboratory. After 44 hours in a sharp freezer at −21° C. (−5° F.), the frozen blocks[4] were bored as described for the first series, and the samples analyzed without delay.

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[4] The melange represented by Sample No. 14 was spilt while being transferred to the sharp freezer, hence no sample of the frozen melange could be obtained.

Since it is well known that many of the organisms in egg melange fail to grow well at 37° C. (7, 13, 15), plates were incubated at 30° C. for 3 days. To obtain some indication of the comparative counts, additional sets of plates from the fresh melange, and from the frozen melange 48 hours later, were incubated at 37° C. for 2 days.

Smears for direct microscopic counts were prepared from the 1:10 dilution of melange, 0.01 ml. being spread over a circular area of 1 cm.^{2}. Those from Series I were stained for 15 to 30 seconds with Gray's (2) stain diluted with 2 parts of water, those from Series II with North's stain (8).

Coliform organisms were estimated using brilliant green bile broth (6), and positive tubes showing black and metallic colonies were considered as containing *Escherichia coli.*

To obtain some idea of the effect of freezing on the flora of the melange, from 70 to 84 colonies were picked from entire plates or segments of plates poured for each of the 4 fresh samples in Lot C (June 7) Series I. This was repeated when re-sampling after storage for 6 months. Cultures were purified and, on the basis of macroscopic and microscopic appearance, supplemented by physiological characteristics, placed in their respective genera.

RESULTS

For Series I plate counts for individual samples are shown in Table 1, and direct microscopic counts in Table 2. The general effect can more readily be grasped from Figure 1, where the average values for all samples in Lots B and F are shown graphically.

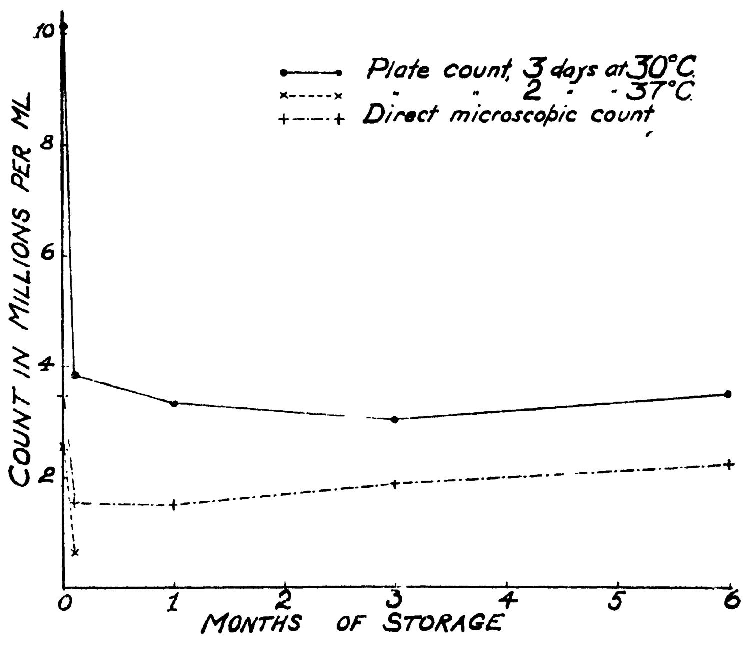

FIGURE 1.—Effect of freezing and subsequent storage on bacterial content of egg melange. (Average of 20 samples).

The results of coliform and *E. coli* determinations for Lot C are shown in Table 3. For Lot A, the dilutions employed were too high, and for the remainder too low, to permit satisfactory calculation of the most probable numbers present, hence data for these lots have been omitted.

The results of the studies on flora of fresh and frozen melange are summarized in Table 4.

For Series II, plate and microscopic counts on fresh and frozen melange are shown in Table 5, together with the percentage survival for each individual sample.

DISCUSSION

The results from Series I show an average reduction in the 30° C. plate count of nearly two-thirds as a result of freezing. On subsequent storage for periods up to 6 months, further changes were slight. The reduction on individual samples in this series ranged from 13 to 87%, with an average of 64.2%. In Series II (Table 5) the average reduction was of the same magnitude (61.66%) but there was less variation between individual samples, values for which ranged from 41.5 to 73.3% reduction. These results are in contrast to those of Holtman (3), who found a 99% reduction in total count after 7 to 9 months storage in a frozen condition (−5° to 0° C. (23° to 32° F.)). This greater reduction may be due to the higher storage temperature; Jensen (5) reported "destruction of bacteria in frozen-egg magma . . . . . . is most rapid when the products are stored at −6.7 to −3.9° C. (20° to 25° F.)."

That a similar reduction in count takes place when melange of lower initial bacterial content is frozen is indicated by data recently furnished by Mr. E. W. Noton, resident inspector for the Special Products Board at Winnipeg. Cartons containing 7 oz. of freshly prepared melange were held in a freezer at −15° to −6° F. (−26° to −21° C.) from June 12 to June 27, 1945, when a chip of frozen melange was removed from each carton, defrosted and analyzed. The remaining contents were then defrosted at room temperature (74° F.), taking 5 hours to defrost completely. After thorough stirring with a sterilized spoon, a second analysis was conducted. Bacteria counts were estimated by means of the Burri slant technique (9), slants being incubated at room temperature for 3 days. The results (Table 6) indicate a reduction in count comparable to that obtained with high count melange by the plate count method (Table 1). The data in the final column, representing analyses of the entire contents of the cartons on defrosting, suggest that some growth took place during defrosting of the remaining contents.

As anticipated, the counts at 37° for 2 days were much lower than those at 30° for 3 days. The average initial 37° count was 25.4% of the 30° count, while that after 48 hours freezing was 21.9% of the 30° count at that time.

As might be expected from the irregular distribution of bacteria in melange (7) the microscopic counts (Table 2) showed considerably more variability than did the plate counts (Table 1). Surprisingly, the microscopic counts were, with rare exceptions, considerably lower than the 30° plate counts, although generally higher than the 37° counts (Figure 1).

Lower microscopic counts than 30° plate counts were also encountered in Series II (Table 5), although the percentage surviving freezing was much higher than that indicated by the plate count. While a few of the samples reported on by Lepper, Bartram and Hillig (11) showed lower microscopic counts, in most instances the plate counts after 72 hours at 32° C. were lower both before and after freezing. Our results with fresh and frozen melange are in sharp contrast to those obtained with whole egg powder (6, 8, 11) using North's stain and incubation of plates at 37° C. for 48 hours. (With powder, plate counts at 30° in 1943 were comparable to those at 37°, although significantly higher 30° counts were obtained in some recent studies (7)). These results suggest either that certain bacteria in melange fail to stain, or else that some are lost from the smear during defatting, fixing, staining and washing The irregular distribution of bacteria in melange, previously mentioned, scarcely affords an adequate explanation of the generally lower level of microscopic counts.

Freezing appeared to reduce the coliform content of melange in much the same way as it did the total count (Table 3). The *E. coli* content, on the other hand, appeared to be more variable and did not show much drop until after 3 months. The reduction in coliforms is, however, much less marked than that reported by Holtman (3).

The studies on the effect of freezing upon the bacterial flora yielded rather inconclusive results (Table 4). Some surprisingly large differences were noted between the various samples in a given lot. There is some indication that freezing may reduce the proportion of *Pseudomonas* species, a definite drop being noted for each of the four samples analysed. This is in agreement with the findings of Lochhead and Jones (12) that organisms in frozen-pack vegetables developing at 4° C. (39.1° F.) were least resistant to freezing. In our studies the number of cultures was too small to warrant the drawing of very definite conclusions.

It was thought that freezing might result in uneven distribution of the organisms within the frozen block. If ice crystals form first at the periphery, the egg solids and accompanying bacteria might be expected to become concentrated toward the center (1, 14). To check on this possibility, borings were made in the center, near the end of the block, and midway between the first two borings. Separate portions were obtained for each boring from the top 2 inches, 2 to 4 inches, and 4 to 6 inches deep. Two blocks, one from Lot D and one from Lot E, were sampled in this manner after 6 months' storage. In addition to plate counts at 30° C., total solids were determined. Contrary to expectations, the highest counts and total solids were found in the top 2 inches, while counts and solids from the center core were lower than those from the end of the block (Table 7). Somewhat similar counts were obtained by Holtman (4).

It will be observed that in both series the level of counts is far above that ordinarily encountered in melange prepared from good quality eggs. Lepper, Bartram and Hillig (11) state, "In no instance did dried eggs show a microscopic count exceeding 10 millions per gram or frozen eggs 5 millions per gram when they were prepared from sound raw material. In all cases where these counts were exceeded, decomposed or rotten eggs had been

incorporated in the product or the eggs had been subjected to conditions after breaking-out which permitted them to sour." In our studies we have good reason to believe that neither of the above-mentioned conditions was responsible for the high level of counts. Only graded eggs, preponderantly Grade A, were used. They had been in storage for from several weeks to 3 months; all were examined for odour and appearance on breaking and any of doubtful quality rejected. Plant sanitation was generally satisfactory in both plants, regular check-ups being made by the resident inspectors and plant laboratories, supplemented by occasional sanitation surveys conducted by the senior author. In no instance were conditions or practices encountered which could conceivably result in counts of the magnitude recorded. Studies reported in another paper (10) suggest that high counts on eggs throughout Canada during the summer of 1944 were attributable to a small percentage of apparently normal eggs which contained very large numbers of bacteria. These bacteria were able to penetrate the intact shell of new-laid eggs and to grow to enormous numbers without causing sufficient change in either odour or appearance to warrant their rejection by the breakers.

SUMMARY

The freezing process brought about a sharp reduction in the numbers of bacteria present in whole egg melange. In two series of tests, involving 44 samples, the average reduction in count was nearly two-thirds. Subsequent storage at 5° F. (−15° C.) for 6 months resulted in little further change in count, although *Escherichia coli* appeared to die off after 3 months.

Plate counts at 37° C. for 2 days were less than a quarter of those at 30° C. for 3 days. Direct microscopic counts were almost always lower than plate counts at 30° C. No explanation for this anomaly has been found.

Freezing and subsequent storage for 6 months appeared to reduce the proportion of *Pseudomonas*, but other genera showed variable results.

There was no indication that the freezing process led to a concentration of bacteria and egg solids in the center of the frozen block.

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TABLE 1.—EFFECT OF FREEZING AND SUBSEQUENT STORAGE ON PLATE COUNTS OF EGG MELANGE. SERIES I

(Counts in thousands per milliliter)

Sample No.	Prepared for freezing	Before freezing		After 48 hours		After 1 month	After 3 months	After 6 months
		A*	B*	A	B	A	A	A
A 1†	May 8	40	7.7	74	12	—	—	—
2		360	58	180	23	—	—	—
3		750	—	320	—	—	—	—
4		340	—	160	—	—	—	—
B 1	June 5	19,000	2,900	4,000	790	3,100	1,000	3,000
2		16,000	3,300	7,300	1,000	6,000	4,400	4,800
3		16,000	3,500	6,600	900	5,900	2,100	4,400
4		15,000	2,500	7,900	1,300	5,500	2,100	5,700
C 1	June 7	7,000	2,100	2,300	530	1,600	2,000	2,300
2		6,900	2,000	1,900	390	1,800	2,500	2,600
3		10,000	2,500	2,500	670	3,300	2,900	2,200
4		12,000	3,800	2,600	500	2,900	3,200	2,900
D 1	July 3	5,000	960	1,100	310	820	290	620
2		6,900	890	1,100	290	840	290	730
3		4,000	960	1,100	430	610	290	880
4		3,400	650	1,100	420	780	520	690
E 1	July 10	10,000	4,100	4,000	740	3,000	3,600	4,500
2		10,000	2,200	4,900	670	4,700	6,900	6,400
3		5,300	1,100	690	150	990	930	1,500
4		16,000	8,000	4,200	710	2,400	4,500	6,400
F 1	Aug. 2	9,900	—	8,600	—	7,900	8,400	8,200
2		9,700	—	6,600	—	6,600	6,300	6,500
3		13,000	—	6,600	—	5,300	3,200	4,400
4		8,100	—	1,400	—	3,500	2,100	1,600

* A = Incubation at 30° C. for 3 days; B = at 37° C. for 2 days.
† This mould was erroneously placed in a warmer room than the other 3, and except for a crust on the surface was still liquid when sampled after 48 hours.

TABLE 2.—EFFECT OF FREEZING AND SUBSEQUENT STORAGE ON DIRECT MICROSCOPIC COUNTS OF EGG MELANGE. SERIES I

(Counts in thousands per milliliter)

Sample No.	Prepared for freezing	Before freezing	After 48 hours	After 1 month	After 3 months	After 6 months
A 1	May 8	<70	<70	—	—	—
2		<70	<70	—	—	—
3		150	<70	—	—	—
4		150	<70	—	—	—
B 1	June 5	7,300	510	880	340	2,300
2		6,300	1,500	1,500	660	2,600
3		6,000	1,700	1,800	660	1,800
4		5,900	1,200	810	880	2,000
C 1	June 7	730	510	880	590	1,400
2		1,700	1,100	590	660	590
3		1,600	1,200	810	590	370
4		2,200	810	590	940	1,500
D 1	July 3	1,800	1,800	340	370	150
2		1,800	1,500	340	290	370
3		1,500	880	290	370	660
4		3,700	2,500	340	730	810
E 1	July 10	2,100	3,100	1,100	5,900	3,400
2		1,500	3,800	2,100	6,100	8,900
3		940	730	590	2,100	1,800
4		3,200	2,000	1,200	3,700	3,300
F 1	Aug. 2	5,100	3,700	5,000	4,500	2,800
2		5,700	3,200	5,800	4,600	5,800
3		5,200	2,200	2,800	1,600	2,100
4		5,800	1,200	2,400	1,800	1,500

TABLE 3.—EFFECT OF FREEZING AND SUBSEQUENT STORAGE ON THE COLIFORM AND *E. coli* CONTENT OF EGG MELANGE. (SERIES I)

(Counts as most probable numbers per 100 ml.)

Sample No.	Before freezing		After 48 hours		After 1 month		After 3 months		After 6 months	
	Coliform	*E. coli*	Coliform	*E. coli*	Coliform	*E. coli*	Coliform	*E. coli*	Coliform	*E. coli*
C 1	920	79	240	45	350	20	350	110	240	0
2	240•	45	240	45	350	41	240	79	350	18
3	1600	69	350	79	240	45	350	79	350	0
4	920	45	350	79	350	20	240	0	240	0

TABLE 4.—TYPES OF ORGANISMS ISOLATED FROM FRESH AND FROZEN MELANGE. LOT C, SERIES I

Genus	Fresh melange					Melange frozen 6 months				
	C 1	C 2	C 3	C 4	Average for lot	C 1	C 2	C 3	C 4	Average for lot
	%	%	%	%	%	%	%	%	%	%
Proteus	28.2	31.5	33.8	19.0	27.9	12.7	41.0	45.8	41.8	35.1
Flavobacterium	22.5	13.7	36.3	50.0	31.5	17.3	32.0	35.6	33.0	29.5
Pseudomonas	39.5	23.3	16.2	15.5	23.1	20.0	16.7	8.6	12.7	14.6
Achromobacter	5.6	23.3	2.5	10.7	10.4	29.4	7.7	7.1	12.7	14.2
Bacterium	2.8	5.5	10.0	2.4	5.2	7.0	1.3	—	—	2.0
Serratia	1.4	2.7	—	—	1.0	13.4	1.3	2.9	—	4.3
Bacillus	—	—	—	2.4	0.6	1.4	—	—	—	0.3
Sarcina	—	—	1.3		0.3	—	—	—	—	—
No. of cultures	71	73	80	84	—	75	78	70	79	—

TABLE 5.—EFFECT OF FREEZING ON COUNTS OF EGG MELANGE. SERIES II. (AUG. 23-25, 1944)

(Counts in thousands per milliliter)

Sample No.	Before freezing		After 44 hrs. freezing		Survival	
	Plate	D.M.	Plate	D.M.	Plate	D.M.
					%	%
1	8,400	3,700	2,300	—	27.4	—
2	7,700	8,600	3,900	11,000	50.6	128.0
3	11,000	6,400	3,800	6,500	34.5	101.3
4	9,500	5,700	5,100	5,900	53.7	103.8
5	10,000	4,800	3,100	2,400	31.0	49.0
6	13,000	7,300	7,600	6,300	58.5	86.3
7	11,000	5,400	3,200	5,200	29.1	96.4
8	16,000	8,500	4,900	4,800	30.6	56.4
9	9,900	7,400	2,700	2,000	27.3	27.0
10	8,700	5,600	2,500	2,300	28.7	41.1
11	12,000	5,600	3,200	3,200	26.7	57.2
12	12,000	5,100	4,200	2,300	35.0	45.1
13	20,000	5,600	6,100	5,600	30.5	100.0
14	19,000	4,800	—	—	—	—
15	13,000	6,400	6,200	2,800	47.7	43.7
16	17,000	11,000	7,400	8,400	43.5	76.4
17	20,000	9,500	10,000	7,300	50.0	76.9
18	16,000	7,800	8,500	5,700	53.1	73.1
19	21,000	9,300	8,700	7,800	41.4	83.9
20	25,000	9,500	7,300	7,300	29.2	76.9
Average					38.34	73.47

TABLE 6.—EFFECT OF FREEZING AND SUBSEQUENT STORAGE ON BACTERIAL CONTENT OF MELANGE. BURRI SLANT TECHNIQUE. DATA FURNISHED BY E. W. NOTON

(Counts in thousands per milliliter)

Carton No.	At start	After 15 days frozen	
		Chip defrosted	Entire contents defrosted
1	100	42	80
	110	—	76
2	310	140	230
	320	—	260
3	330	200	230
	340	—	260
4	280	130	200
	290		160
5	10	12	14
	8	—	12

TABLE 7.—DISTRIBUTION OF BACTERIA AND SOLIDS IN BLOCKS OF FROZEN MELANGE

(Bacteria counts in thousands per milliliter)

—	End of block		Intermediate	Center of block	
	Count	Solids	Count	Count	Solids
		%			%
D 3					
Top 2″	1,400		1,200	670	31.48
2″–4″	1,100	30.32	1,800	760	28.42
4″–6″	1,300		690	630	27.74
E 3					
Top 2″	2,100		1,100	1,100	29.71
2″–4″	1,200	28.75	810	920	27.88
4″–6″	840		840	880	27.14

THE EFFECTS OF A VITAMIN B MIXTURE, OF LEVEL OF PROTEIN, AND OF PROPORTION OF PROTEIN OF ANIMAL ORIGIN IN THE SUPPLEMENTS TO BARLEY AND TO WHEAT IN THE BACON HOG RATION[1]

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Comparative hog feeding tests carried out at this Station have brought to light real differences in feeding value between wheat and barley. Most of the differences have appeared to be consequences of the tendency of wheat to stimulate greater fattening than does barley. This may in part be related to a greater percentage of total digestible nutrients in wheat, but in addition seems to be specifically influenced by the greater content of vitamin B complex of wheat. There is also the possibility that differences in the protein make-up of these two grains affects their nutritive value for hogs. Thus the kind of protejn supplement to be used with respect to the proportions of proteins from animal as against plant sources, and the level of the vitamin B complex to be sought by feed selection or specific fortification might differ depending on whether wheat or barley was to be the basal feed.

It was to obtain data on these questions that a feeding trial involving 128 Yorkshire pigs was undertaken in the spring of 1944. The detail of the rations fed and of the plan of the test are shown in Figure 1.

For the first replicate 64 May-born pigs were allotted at random to the several sub-groups, subject to the restriction of equal numbers of males and of females in each treatment group. A second replicate was subsequently fed using January-born pigs.

In each case the pigs were placed on test within a week following weaning at about 8 weeks of age. Throughout the feeding, pigs were confined to individual pens thus permitting individual feed intake records.

The results of the trial were measured in terms of gains of the pigs, their feed consumption under full feeding, shipping weight, and the following carcass characteristics: length of side, depth of shoulder and back fat, leanness of bacon rasher, carcass score and grade.

The length of side was measured in inches from the first rib to the aich bone; leanness of bacon rasher by the square-inch surface area of the "pork-chop" muscle cut betw. n the third and fourth lumbar vertebrae, and also by a planimeter measurement of the surface areas of lean in the full bacon rasher cut as above; carcass score was calculated in accordance with the values used by the Canadian Swine Advanced Registry scheme of carcass evaluations; and carcass grade was set by official graders of the Department of Agriculture.

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[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., Canada. Journal Series No. 212

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FIGURE 1.—DESIGN OF FEEDING TEST

Basal feeds	Vitamin B supplement	Season	Sex	Normal (15.2%) protein level: 5.6 Tankage, 5.6 Oilmeal, 2.8 Minerals, 86.0 Basal feeds; Protein of animal origin 2.8%	Normal (15.2%) protein level: 2.8 Tankage, 8.4 Oilmeal, 2.8 Minerals, 86.0 Basal feeds; Protein of animal origin 1.4%	Reduced (13.4%) protein level: 2.8 Tankage, 2.8 Oilmeal, 2.8 Minerals, 91.6 Basal feeds; Protein of animal origin 1.4%	Reduced (13.4%) protein level: 1.4 Tankage, 4.2 Oilmeal, 2.8 Minerals, 91.6 Basal feeds; Protein of animal origin 0.7%
No. 2 feed barley	Control	Jan. pigs	♂	2 pigs			
			♀	2 pigs			
		May pigs	♂		2 pigs		
			♀		2 pigs		
	Vitamin B complex*	Jan. pigs	♂			2 pigs	
			♀			2 pigs	
		May pigs	♂				2 pigs
			♀				2 pigs
Durum wheat	Control	Jan. pigs	♂	2 pigs			
			♀	2 pigs			
		May pigs	♂		2 pigs		
			♀		2 pigs		
	Vitamin B complex*	Jan. pigs	♂			2 pigs	
			♀			2 pigs	
		May pigs	♂				2 pigs
			♀				2 pigs

* Mixture added at rate of 0.36 grams per 100 lb. feed intended to supply 3, 5, and 10 milligrams of thiamine, riboflavin, and niacin, respectively, per 100 lb. live weight of pig.

The design permitted an analysis of variance of these items (excepting grade) according to the following scheme:

Source of variation	Degrees of freedom	
All causes		127
Between sub-groups		63
January- vs. May-born pigs	1	
Male vs. female	1	
B complex vs. nil	1	
High vs. low protein	1	
50% vs. 25% animal protein	1	
Barley vs. wheat	1	
Interaction	57	
Within sub-groups (error)		64

The findings of this test may perhaps best be presented according to the separate criteria used. In general only comparisons which show differences of statistical significance or appear to have practical importance will be shown or commented upon.

Seasonal Differences

The effects of season, especially on carcass excellence were of some consequence.

TABLE 1.—MAY- VS. JANUARY-BORN PIGS

Season	Daily gain	Daily feed	Grade A* carcasses	Eye of lean in pork-chop at 3rd lumbar vertebra	Length of carcass, 1st rib to aich bone	Depth of fat		Lean in bacon rasher
						Maximum shoulder fat	Minimum back fat	
	lb.	lb.	%	sq. in.	in.	in.	in.	%
May-born	1.19	5.7	55	5.14	29.6	1.70	1.09	42
January-born	1.25	5.1	28	4.42	30.3	1.91	1.35	35

* In Canada a bonus of $3.00 is paid over the base bacon carcass price for each carcass graded A, and $2.00 for grade B.

These seasonal differences include a change in the breeding of the pigs. The January-born and May-born pigs were sired by different boars, and it is evident from other data in our herd that the sire of the January-born pigs caused an increase in the length of the carcasses. This increase in length of side would be expected to be correlated with a leaner carcass and perhaps also with a higher grading. This, however, is not shown in the above data. January-born pigs were fatter, of lower grade, and were considerably faster gaining in spite of lower feed intake.

The May-born pigs were fed for the last month or more of their fattening during cold weather, while the January-born pigs were finished during the summer. Our records show that cold weather results in slowing of rate of gain where pigs are kept in unheated quarters. There is evidence, both experimental[4] and from actual farm practice, that cutting the rate of gain during the latter part of the finishing period results in an increase in carcass leanness. It seems probable that this is the explanation of the seasonal differences in carcass quality noted in this test. (These seasonal effects do not disturb interpretation of the other comparisons, since they were equally distributed to all treatments).

Male vs. Female Pigs

Marked sex differences were found in this trial as shown in Table 2. Males produced fatter carcasses, and as a penalty, fewer grade A's.

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TABLE 2.—EFFECT OF SEX ON CARCASS EXCELLENCE

Season	Daily gain	Daily feed	Grade A* carcasses	Eye of lean in Pork-chop t 3rd ' umbar vertebra	Length of carcass, 1st rib to aich bone	Depth of fat		Lean in bacon rasher
						Maximum shoulder fat	Minimum back fat	
	lb.	lb.	%	sq. in.	in.	in.	in.	%
Males	1.32	5.46	30	4.33	29.7	1.87	1.28	37.7
Females	1.12	5.31	54	5.24	30.2	1.75	1.15	40.0

These findings emphasize the necessity of careful design in tests of this nature to avoid masking or biasing the results of imposed experimental treatments.

The Effect of the Vitamin B Supplement

The effects of supplementary allowances of thiamine, riboflavin, and niacin are summarized in Table 3

TABLE 3.—EFFECTS OF SUPPLEMENTARY VITAMIN B

Vitamin supplement	Daily gain	Daily feed	Grade A carcasses	Lean of bacon rasher	Maximum shoulder fat
	lb.	lb.	%	%	in.
Barley					
Vitamin B complex	1.26	5.77	40	40.1	1.79
Nil	1.27	5.68	53	39.6	1.75
Wheat					
Vitamin B complex	1.19	5.01	25	36.8	1.92
Nil	1.17	5.08	48	38.9	1.78
Normal protein					
Vitamin B complex	1.27	5.46	34	39.8	1.81
Nil	1.32	5.69	45	38.9	1.78
Reduced protein					
Vitamin B complex	1.18	5.32	28	37.1	1.90
Nil	1.12	5.08	56	39.5	1.77
Normal animal protein					
Vitamin B complex	1.24	5.4	31	38.5	1.91
Nil	1.20	5.3	56	39.8	1.75
Reduced animal protein					
Vitamin B complex	1.21	5.4	34	38.4	1.80
Nil	1.24	5.4	44	38.6	1.78
Vitamin B...all combinations	1.23	5.39	32	38.5	1.85
Nil..........all combinations	1.22	5.38	51	39.2	1.76

The effects of the fortification of the diets with these members of the vitamin B family are interesting and are in accordance with expectation on the basis of theory and of previous findings at this Station.

Extra vitamin B has damaged the average carcass grading, and evidently because of over-finish. Since there were no significant differences in rate of gain or feed intake, it may be concluded that the B complex has stimulated the synthesis of fat from the feed eaten beyond that which would have occurred otherwise.

Furthermore, these effects were more pronounced on the wheat than on the barley rations, and on the reduced than on normal dietary protein levels. The former would be expected in view of the especially high B complex in wheat, while the latter follows from the more fattening character of the lower protein rations.

Normal vs. Reduced Protein

The protein comparison (Table 4) involves both level and kind of protein. The chief significant effect of the high (15%) vs. low (13%) protein levels of the ration was in rate of gain. The pigs on the lower protein level gained 0.15 lb. less per day and required 15 days longer to reach market weight than those on normal protein levels.

TABLE 4.—EFFECT OF PROTEIN LEVEL AND PROPORTION OF ANIMAL PROTEINS IN RATION

Protein level	Normal animal protein		Reduced animal protein		All pigs	
	Grade A carcasses	Daily gain	Grade A carcasses	Daily gain	Grade A carcasses	Daily gain
	%	lbs.	%	lbs.	%	lbs.
Normal protein	47	1.28	35	1.32	42	1.30
Reduced protein	40	1.16	43	1.13	42	1.15
All pigs	43	1.22	39	1.22		

Carcass grades showed some interaction between protein level and the proportion of animal protein. Whether or not this interaction is a real effect cannot be stated from statistical analysis, since "carcass grade" does not lend itself to an analysis of variance.

It will be noted that rate of gain was not associated with any difference in carcass grade. This might be taken as contradictory to the interpretation made relative to differences between May- and January-born pigs earlier in the report. However, examination of the data for the pigs at the 100-pound weight reveals no difference between seasons in the rate of gains up to that time (May-born 1.05 lb.; January-born 1.08 lb.) There was, however, 0.1 lb. more daily gain made by pigs on the high than on the low protein rations. Thus the difference in gains due to protein level extended over the whole feeding period, while the effect of gain on carcass quality has, in other experiments, been found only when rapidly gaining young pigs have been restricted in gain during the *latter part* of their fattening period.

Decreasing the proportion of animal protein from "normal" did not influence rate of gain. Whether or not the slightly higher carcass grade on the higher percentage animal protein is significant cannot be stated since it was not possible to apply statistical analysis to the grading records.

TABLE 5.—COMPARISON OF BARLEY VS. WHEAT AS BASAL FEEDS IN RATIONS SUPPLEMENTED DIFFERENTLY AS TO KIND AND AMOUNT OF PROTEIN AND WITH A VITAMIN B MIXTURE

—	Daily feed eaten	Daily gains Observed	Daily gains Adjusted to equal feed intake	Grade A carcasses	Carcass score	Maximum depth neck fat	Eye of lean of chop at lumbar vertebra
	lb.	lb.	lb.	%	%	in.	sq. in.
Males							
Barley	5.8	1.35	1.25	31	66	1.82	4.4
Wheat	5.2	1.29	1.34	28	61	1.92	4.2
Females							
Barley	5.7	1.18	1.11	63	74	1.72	5.3
Wheat	4.9	1.07	1.19	45	70	1.78	5.2
Normal protein							
Barley	6.0	1.35	1.20	47	73	1.77	4.9
Wheat	5.2	1.25	1.30	35	68	1.81	4.8
Reduced protein							
Barley	5.5	1.19	1.17	47	67	1.76	4.8
Wheat	4.9	1.11	1.23	37	63	1.88	4.7
50% animal protein							
Barley	5.8	1.28	1.13	44	71	1.81	4.8
Wheat	5.0	1.16	1.32	44	67	1 85	4.8
25% animal protein							
Barley	5.7	1.25	1.15	50	69	1.72	4.8
Wheat	5.1	1.20	1.29	29	65	1.85	4.6
Vitamin B							
Barley	5.8	1.26	1.13	40	69	1.79	4.8
Wheat	5.0	1.19	1.32	25	65	1.92	4.7
No Vitamin B							
Barley	5.7	1.27	1.15	53	70	1.75	4.8
Wheat	5.1	1.17	1.30	48	67	1.78	4.8

Barley vs. Wheat

Comparison of barley vs. wheat under the several different conditions of feeding is summarized in Table 5.

Our results have indicated that larger amounts of barley than of wheat rations are consumed by pigs during the period from weaning to market weight, and in consequence the observed gains are somewhat greater. However, the gain per unit of feed eaten is significantly larger on the wheat rations. It might be thought that some of the barley fed had been wasted, especially by the small pigs, thus giving an apparent but not really greater feed intake; were it not for the larger gains made on the barley.

There can be no doubt that wheat feeding results in lower carcass excellence than is obtained with barley.

Protein level appears to have the same general effect on barley as on wheat rations. Reduction of the animal protein, however, has appar-

ently been more serious with wheat rations than with the barley diets. With the larger allowance of animal protein there was no significant effect related to barley vs. wheat.

The unfavourable results, especially on the wheat rations of vitamin B supplement are clearly evident in carcass grade and depth of shoulder fat.

CONCLUSIONS

1. Season may be an important factor in the excellence of bacon carcasses produced. If pigs are finished in winter in cold pens the rate of gain may be sufficiently reduced to result in a superior carcass.

2. Carcasses from male pigs are by nature fatter than those from females. The tendency for wheat as compared to barley to damage carcass excellence is more pronounced with male than with female pigs.

3. Special supplementation with a mixture of thiamine, riboflavin and niacin tended to aggravate the already greater tendency of wheat than of barley to produce fat carcasses.

4. Reduction of the protein level of the ration from 15% to 13% was reflected in lower feed intake, and slower gains but did not affect carcass excellence regardless of whether wheat or barley was the basal feed.

5. Halving the proportion of the protein from animal origin had no measurable effect either on the progress of the live pigs or on the excellence of the carcasses. Apparently 1.4% of protein of animal origin in the ration—equivalent to only 9% of the protein of a ration carrying 15% protein—is as satisfactory as is double this amount.

ACKNOWLEDGMENT

We are indebted to the Canadian Co-operative Wheat Producers for their continued interest and financial support of these studies on the feeding values of the cereal grains for swine, and to Canada Packers for the use of abattoir facilities and for absorbing losses incidental to cutting the carcasses.

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DETECTION OF THE LOOSE SMUT FUNGI IN EMBRYOS OF BARLEY AND WHEAT[1]

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The loose smuts of barley and wheat, caused by *Ustilago nuda* (Jens.) Rostr. and *U. Tritici* (Pers.) Rostr., respectively, although not usually of great economic importance have always been troublesome, especially to the seed grower. Both cause considerable loss when the incidence is high, and both are difficult to detect in seed samples and to control.

In Western Canada, a few fields of barley are reported each year which show infestations up to 20% of the plants. This represents, in most cases, a direct loss of about that amount. Usually, most fields show much less, but the annual surveys indicate that loose smut is nevertheless quite prevalent. The situation is much the same for wheat except that the infestations are usually less severe. Until recently, the barley loose smut records included both the true or internally-borne type (*U. nuda*), and the false or shallow-borne type (*U. nigra* Tapke). The discovery by Tapke (9) of a seedling-infesting loose smut of barley and his later work has cleared up many confusing questions in barley smut investigations.

The prevalence and sporadic occurrence of loose smut in both barley and wheat have been a source of considerable annoyance, rather than anxiety, to the seed inspector and seed merchant. Field inspections must be depended upon in efforts to determine true loose smut infections, and these are not wholly satisfactory.

TESTING SEED SAMPLES FOR LOOSE SMUT

To determine the percentage of loose smut in seed, the pathologist has usually resorted to a growing test. Greenhouse trials are fairly satisfactory but are time and space consuming. In greenhouse tests with smutty barley samples, a seed treatment with a mercury dust can be applied to eliminate the surface-borne smuts and so give a determination of true loose smut. Such a growing test has been conducted as a matter of routine on many barley samples by Dr. R. C. Russell of this Laboratory. In our first attempt (7) to outline a procedure for seed examination, a mature plant test was suggested for loose smuts as well as for barley stripe. Until recently the alternative to the growing test was to soak the seed,

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tease out the embryos, and fix, wash, dehydrate and embed them, following the usual histological technique. Sections were then made and stained. The method gives good results but is impracticable for routine examination.

There have not been many reports on routine methods for detecting loose smut infections. Contributions by Russian scientists, however, have thrown some light on the problem. Bubentzoff (2) developed a method for isolating *U. Tritici* from wheat seed; and, according to an abstract of the paper, it appears very promising. Saburova (6) states that loose smut infections of wheat can be determined by observing certain abnormalities in the ears of seedlings less than a month old. Later, Skvortzoff (8) used a maceration and staining technique on separated embryos to demonstrate infections by *U. Tritici*. More recently, Yablokova (10) reported on the application of fluorescent microscopy to the detection of *U. Tritici*. These four approaches deserve further study.

OBSERVATIONS ON SEPARATED EMBRYOS

From the start of cereal seed examination for disease as a routine procedure here, we have been confronted with the problem of detecting loose smut. During the past few years many attempts have been made to devise quick and reliable methods of diagnosis. The histological approach was explored and seemed promising, provided the embryos could be separated and handled in sufficient mass. Attention was directed therefore towards methods of embryo separation or removal. Maceration treatments were tried, and it was soon discovered that solutions of sodium or potassium hydroxide were surprisingly effective. It appears that these solutions cause a swelling of the endosperm starch coincident with a general softening and dissociation of the adhering hulls in barley and the pericarp and testa in both grains. This results in the release of the complete embryo without any noticeable distortion.

Embryo Separation

In most of our work, a 5% sodium hydroxide solution was used. About 30 grams of either barley or wheat seed is placed in a flask and covered with two or three times its volume of the solution. In earlier tests the seeds were pre-soaked in the ice-box overnight, but it is uncertain from later work whether or not pre-soaking is necessary. In 24 hours, free embryos may be seen in the soft gel-like mixture which has formed as the solution has acted on the kernels. These are easily detached by slight agitation upon the addition of water. To obtain more embryos, the mixture may be poured into a large dish and gentle pressure applied with a rubber stopper or some such instrument. A coarse screen will remove the larger fragments, leaving the embryos and smaller endosperm pieces. Finer screens may then be employed until a mixture of embryos and similar sized fragments is obtained. It may be necessary at this point to dip or pick the embryos out, and this was usually done. It is thought, however, that with suitable screening and other minor improvements the method would give a clean separation. Well over 50% of the seed usually release their embryos without much trouble, and commonly the yield is much better. It is believed that a yield approximating 100% can be expected with a little experience in the technique.

Detecting Infections

Two methods were employed in the examination of embryos to determine the extent of loose smut infection. In the first, or whole embryo method, the technique was kept very simple and with a minimum of manipulation the entire embryos were prepared for examination in the clearing fluid. In the second, or sectioned embryo method, the usual histological technique was employed, the embryos being embedded en masse in wax ready for sectioning. The whole embryo method seems particularly promising and is now described.

The Whole Embryo Method

As mentioned above, the embryos are separated and held in water. (a) They are allowed to remain in an excess of water for a time varying from several hours to overnight. The water may be changed once or twice to leach out most of the sodium hydroxide. (b) The water is drained off and 95% alcohol added. They may remain in this an hour or two. (c) The 95% alcohol is drained off and absolute alcohol added; this may be repeated to assure dehydration. (d) A portion of or the entire sample may then be placed in a syracuse watch-glass, the excess alcohol drained off, and cedar clearing oil added. Clove oil or other clearing solutions may be used but a rather thick cedar oil has been most satisfactory as it keeps the specimens in place when the dish is handled. Clearing begins immediately, and the embryos should be well cleared in an hour or so.

The scutellum is then examined carefully for the rather conspicuous infection foci. The somewhat dark brownish mycelium is easily seen in contrast with the transparent host cells (Figure 1). Frequently the entire scutellum is involved. Foci are commonly seen in the apical part of the scutellum, but almost as frequently they occur in lateral areas of the organ. The epithelium appears to be a favourite site, but the invasion also involves the adjacent parenchyma. The details of the infection can only be determined from sectioned and stained preparations; and these will be discussed later. For the gross examination as outlined in this method, a wide-field binocular was employed giving a magnification of about 70 times. Greater enlargement with a better instrument would no doubt facilitate the reading. Furthermore, it is an advantage if the specimens are arranged in groups or rows in the oil. A dish especially designed to allow the specimens to settle into rows or a dish marked into squares would make counting much easier. In cases of doubt, the embryo can be dissected and examined in greater detail.

Staining the whole embryo for examination needs further study, but the unstained preparations have proven surprisingly satisfactory.

The Sectioned Embryo Method

In this method, as mentioned above, the embryos are prepared for sectioning. Starting at step (b) as above, the specimens are transferred to 70 or 85% alcohol, then through the usual butyl-ethyl alcohol solutions to pure butyl alcohol. The specimens are left in the solutions for a period of about 2 hours. (c) Pieces of embedding paraffin are added to the vial containing the specimens in pure butyl alcohol and allowed to dissolve.

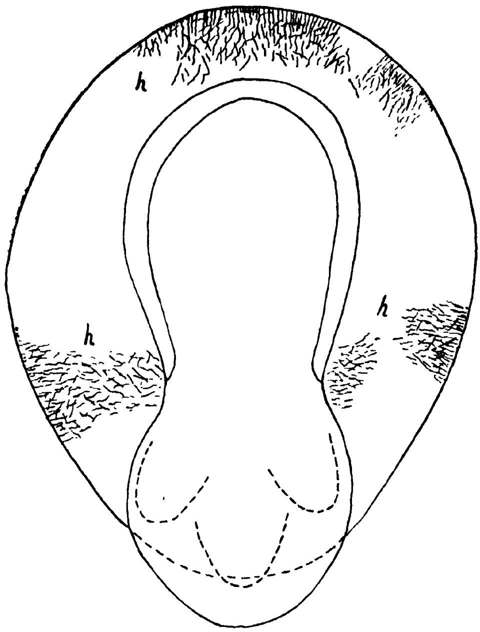

FIGURE 1. An outline sketch of a face view of a separated embryo of barley, showing the large scutellum in which foci of loose smut hyphae (h) may be seen after proper clearing. × 35.

This step is carried out in the wax oven held at 55° C. (d) As the paraffin dissolves, more is added until the specimens in a day or so are in pure paraffin. (e) The specimens are now ready to be transferred to the final embedding container. The size of the tray is quite important as the resulting block of wax should be large enough to contain as many specimens as possible in one plane and yet of a size convenient for cutting. Small porcelain trays (25 × 15 × 8 mm.) in which water-colours are sold were found satisfactory in this work. They were smeared very lightly on the inside with vaseline. To transfer the specimens, the excess wax is poured off and the mass of specimens dumped onto a clean piece of paper. In a moment they have cooled sufficiently to be picked up with a scalpel and placed in the tray, which is then put into the oven. If more wax is needed, it may be added. As the wax melts, the embryos settle to the bottom and upon gentle agitation arrange themselves in layers. In a tray of this size, each layer contains close to 100 embryos, the first layer of course being in the bottom of the tray. (f) The tray is next removed very carefully from the oven and cooled rapidly in ice-water. The block is easily removed and is ready to be placed on the microtome without much, if any, trimming. The block is secured with the bottom surface outward so the first layer of specimens is in position for sectioning. (g) A short ribbon can be taken off to assure contact with most specimens in the layer; then one cut or a short piece of ribbon is saved, and so on until enough material representing the first layer is obtained. The sections for staining are cut at 10μ. The instrument may be adjusted to 20μ or more to remove the remainder of the

first layer; then set at 10μ and specimens from the second layer taken. Likewise the third and additional layers may be sectioned. There is, of course, some overlapping between the layers. A block of the size mentioned will show for each stroke of the knife a group of sections representing as many embryos as are in the layer cut. Because of lack of orientation, sections will be of various sizes and angles, but most will show enough of the scutellum for the detection of the hyphae. Each paraffin section may be spread in the usual way separately on a slide or short ribbons may be used. After drying, the slides are ready for staining. (h) The wax is removed and the slides brought down to 50% alcohol, then placed in Harris' haemotoxylin for ½ hour, washed with 50% alcohol, taken down to water, and placed in 5% aqueous solution of congo red for 3 hours. From here on the usual procedure is followed and the mounts are completed with balsam and cover-slip.

The slides are then ready for examination, and generally there is no difficulty in detecting the invaded embryos (Figure 2). The hyphae take the congo red fairly well, and many excellent preparations have been obtained. It is a simple matter to determine the percentage of embryos infected.

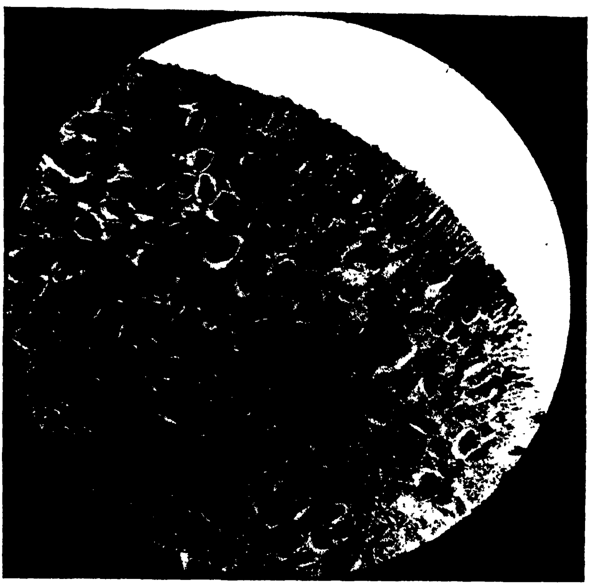

FIGURE 2. Showing a portion of the scutellum with the loose smut hyphae well established in the epithelium and parenchyma. From a section of a barley embryo. × 1000.

Comparative Data

It was difficult to get sufficient seed, especially of wheat, with known high loose smut content. Some samples were obtained, particularly of barley, upon which field notes had been made, and some were grown in the greenhouse for observation. The amount of *U. nuda* and *U. Tritici* was determined in several ways on the same samples (See Table 1).

TABLE 1.—THE AMOUNT OF TRUE LOOSE SMUT IN SAMPLES OF BARLEY AND WHEAT AS DETERMINED BY DIFFERENT METHODS

No.	Sample	Field notes	Greenhouse test	Embryos containing loose smut	
				Whole embryo	Sectioned embryo
		%	%	%	%
1	Glacier barley	21*	21	20	18
2	Reward wheat	4*	—	2	5
3	Reward wheat	—	—	1	—
4	Newal barley (Indian Head)	20*	14	14	11
5	Newal barley (Indian Head)	—	18	25	—
6	Newal barley (Edmonton)	—	10 ±	11	—
7	Newal barley (Swift Current)	—	—	8	—

* Counts based on smutted heads.

It will be seen that determinations by the various methods were in reasonably good agreement. The field notes were made earlier and for another purpose, and the percentage of smut was determined from head counts. In the greenhouse, around 200 plants were grown for smut counts and the percentage was based on the number of smutted plants. In the embryo examination, from 100 to 300 were examined for infection.

The sectioned embryo method, although somewhat more tedious than the whole embryo method, should be very exact and definite. The much faster and simpler whole embryo method, with some practice, should be just as reliable. A little experience would soon reveal varietal or other peculiarities, if any.

DISCUSSION

The main object of this study was to explore methods of examination for the determination of internally-borne loose smut infection in barley and wheat seed. The abundance of the hyphae in the scutellum was observed by Lang (3, 4) for both wheat and barley. He also mentioned a previous and similar observation by Hecke. Brioli and Schikkorra (1), by freehand and microtome sections, demonstrated the loose smut mycelium in the barley scutellum as well as just below the shoot bud. Lang, in describing the parts of the seed invaded, mentioned the heavy brownish mycelium in the embryo of the ripe seed. These characteristic hyphae and the foci of infections in the scutellum directed our attention particularly toward this organ. In the whole embryo method, these foci are quite easily demonstrated.

It was not part of this study to determine the mode of invasion and the final loci of the fungus in the seed. Nevertheless some observations in this connection were possible in the stained preparations of sectioned barley

embryos. There appeared to be no doubt of the heavy invasion of the scutellum, particularly in the area of the scutellar node from whence on the same level the fungus becomes established just below the growing point of the shoot. The scutellum sometimes appears completely invaded. In other specimens, there seem to be small areas involved in the lateral borders or at the tip or base of the scutellum. The epithelium is a favourite site of invasion, with the mycelium packed between the cells, but here and in the parenchyma there is considerable ramification apparently through some cells as well. There were no gross indications of injury; the staining reaction of host cells adjacent to hyphae appeared to be the same as distant cells.

Only one sample of Reward wheat seed was available for study and it did not contain a heavy infestation. The location of the fungus was in general the same as that in the barley embryos.

It was concluded that both methods have some promise as routine tests. There is still plenty of scope for minor modifications in the techniques, although it is thought that the fundamental principles are sound. Furthermore, it is believed that the examination of complete embryos might be applied to studies of viability, frost injury, and various other seed troubles. Preliminary attempts in staining *in toto* were not successful in this special study, but needless to say this phase deserves further study.

In barley seed it is quite important to know whether a surface-borne or an internally-borne smut or both are present in deciding what control treatment to recommend. The methods discussed should be useful in such problems.

SUMMARY

1. The problem of internally-borne loose smut of barley and wheat is reviewed briefly, especially in reference to methods used for the detection of these parasites in seed samples.

2. Two methods are outlined for detecting embryo infection. The embryos are removed by treatment with sodium or potassium hydroxide solutions. In the whole embryo method, they are dehydrated and cleared in cedar oil and examined without staining or sectioning; in the sectioned embryo method, the embryos are embedded, sectioned en masse, and stained. Both procedures gave reasonably good results.

ACKNOWLEDGMENT

The author wishes to acknowledge the helpful suggestions received from Mrs. Nebel and to thank her for examining some of the slides.

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THE PREVALENCE AND CONTROL OF SEED-BORNE DISEASES OF CEREALS IN MANITOBA[1]

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Some of the most destructive diseases of cereal crops (wheat, oats, barley, and rye) in Manitoba are caused by fungi and bacteria that are carried over from one crop season to the next either on the surface of the seed or within the seed. These diseases are commonly referred to as "seed-borne diseases." The seed-borne diseases of cereals of most common occurrence in this province can be grouped into three general classes: (1) smuts, (2) pre-emergence and seedling blights, and (3) leaf and stem spots. The chief crops affected by these are wheat, oats, and barley.

During the 10-year period ending 1937, the average area under field crops in Manitoba was about 6,219,000 acres. Of this acreage, the average sown to cereal crops was 5,616,000 acres (3). Cereals, therefore, occupied more than 90% of the land devoted to field crops. Wheat, of course, is the crop most extensively grown. Owing to the importance of cereal crops in this province, it is obvious that any group of diseases that seriously affects them is of great economic importance. Accurate estimates of losses in Manitoba due to seed-borne diseases of cereals are difficult to arrive at for the reason that information regarding the prevalence and severity of most of these diseases is too incomplete to provide an adequate basis for such estimates. It is generally recognized, however, that seed-borne diseases take a heavy annual toll from every important grain crop throughout the whole province. According to calculations made by Craigie (3), the average annual loss to Manitoba through the cereal smuts alone during the 22-year period 1916 to 1937 was $1,390,000. The seed-borne pathogens that are responsible for pre-emergence and seedling blights and for leaf and stem spots also cause substantial losses year after year in this province.

To obtain more definite information concerning the prevalence, severity, and distribution of seed-borne diseases of cereals in Manitoba, annual seed surveys were made from 1937 to 1942. Each year, from 400 to 1000 samples of cereal seed (wheat, oats, and barley) were examined critically for the presence of disease-producing parasites. The samples were obtained from seed stocks held on farms in Manitoba.

The principal objects of these studies were: (1) to develop reliable and practical methods for the pathological examination of cereal seed, (2) to ascertain the state of health of individual farmer's seed stocks, (3) to determine the fungus flora and the prevalence and severity of disease-producing fungi, (4) to study the relation of certain pathogenic fungi in wheat and barley seed to seed germination, and to the incidence of disease in the subsequent seedling stand, and (5) to determine the effect of seed treatment on the germination of healthy and diseased seed, and on the

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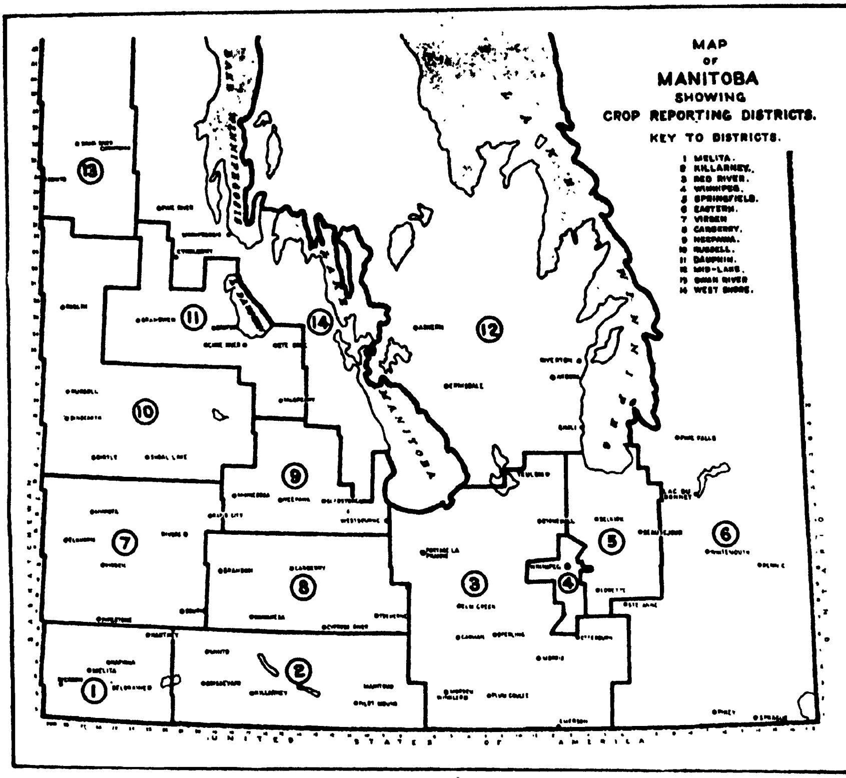

FIGURE 1. Crop reporting districts in Manitoba.

control of seedling-blight and leaf-spot fungi. A preliminary report on these studies has already appeared (6). A detailed account of them is presented in this paper.

MATERIALS AND METHODS OF PATHOLOGICAL SEED ANALYSIS

Samples of seed-grain from the 1937 to 1942 crops were obtained from individual farms in each of the major crop districts of the province (Figure 1). In 1941, for instance, about 40 farms, taken at random in each crop district, were visited. From these farms, 30 samples of wheat seed and 20 each of oat and barley seed were collected for disease examination. The total number of farms in Manitoba from which samples were obtained in 1941 was 520.

From a statistical standpoint, the taking of 520 samples may not constitute an entirely satisfactory sampling of the 56,000 farms in Manitoba, but for all practical purposes it was considered that the seed-grain samples examined in 1941, and in other years of the investigation as well, were representative of the seed stocks held on farms in this province.

In the first two or three years of the investigation, considerable time was devoted to a comparison of different pathological seed testing methods,

and to the development of new ones. The methods finally adopted to ascertain the state of health of each seed sample were: (1) a macroscopical examination of the sample to observe its physical condition and to detect the presence of ergot bodies, smudged kernels, smut balls, etc., (2) an agar-plate test to determine the internal fungus flora of the seed, (3) a microscopical examination of the seed washings to ascertain the spore load of smut and other fungi carried on the surface of the seed, and (4) a non-sterile soil test with disinfected and non-disinfected seed to measure seed germinability, to show the amount of seed-borne disease, and to indicate the response of each sample to seed treatment.

The agar-plate method used was as follows: 100 kernels, taken at random from each sample, were surface sterilized by immersing them in a solution of alcohol and mercuric chloride (1 part of 95% ethyl alcohol to 3 parts of 1 : 1000 mercuric chloride solution). The time of immersion was 4 minutes for wheat and rye, 2 for oats, and 5 minutes for barley. The kernels were then washed 3 times in sterile water. While they were being treated, acidified potato dextrose agar (pH 4.6) was poured into sterile Petri dishes and cooled to a temperature of about 50° C. By means of sterile forceps, the kernels were placed in the soft agar, 10 seeds per dish. The Petri dish cultures were then held at a temperature of from 24° to 26° C. for 8 days. At the end of this period, the organisms growing out from each kernel were either identified at once or isolated for further study and identification. The method described above is essentially similar to that developed and employed by the writers in earlier seed studies (5, 11). In the isolation of the pathogenic fungi found commonly associated with cereal seed, it has given satisfactory results.

The determinations of the smut spore load present on cereal seed samples were made by the method described recently by Cherewick (1). Briefly, it consisted of washing a portion of each sample, and of centrifuging and examining the wash water for the presence of smut and other fungus spores. By means of this test, it was found that a spore load of 1 : 128,000 (1 part of smut to 128,000 parts of seed, by weight) caused as high as 5% infection when the seed was grown under favourable conditions for infection.[3] In the present investigation, spore loads of this order were considered sufficiently high to necessitate seed treatment.

All samples of wheat, oat, and barley seed collected from 1937 to 1942 were grown in non-sterile soil in the greenhouse. Machacek and Wallace (13) reported that non-sterile soil is a satisfactory medium for testing seed germinability and certain seed-borne diseases of cereals. They found that the non-sterile soil test measures two important quantities of each seed lot. namely, (1) the percentage of seeds that are viable, and (2) the percentage of seeds that produce healthy plants. From the grower's standpoint, and in respect to a pathological analysis of the seed, the determination of the latter is the more important. When disinfected and non-disinfected seed is used, the non-sterile soil test also indicates the response of each seed lot to seed treatment.

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[3] Unpublished data of Mr. W. Popp, Dominion Laboratory of Plant Pathology, Winnipeg, Man. The writers are indebted to Mr. W. Popp and Dr. W. J. Cherewick of this Laboratory for carrying out the smut tests reported in this paper.

Throughout the present investigation every effort was made to standardize and to employ procedures that would give a reliable estimation of the disease factor in the seed, and facilitate an accurate determination of other factors that are considered important in the appraisal of lots of cereal seed for seeding purposes. In othei words, tests for seed-borne diseases were made in conjunction with tests of seed germinability. The more important results of the pathological seed tests described above are reported in this paper.

EXPERIMENTAL RESULTS

Seed-borne Diseases of Cereals in Manitoba

The seed-borne diseases of wheat, oats, barley, and rye of most common occurrence in Manitoba are listed in Table 1. Some of these, particularly the smuts, are of great economic importance, while others, although present almost every year, cause little damage in this province. In occasional years, however, some of the latter may cause appreciable loss.

Table 1.—List of the important seed-borne diseases of wheat, oats, barley, and rye in Manitoba, and their causal organisms

Crop, and common name of disease	Causal organism
Wheat	
Bunt, or covered smut	*Tilletia Tritici* (Bjerk.) Wint. and *T. laevis* Kuhn
Loose smut	*Ustilago Tritici* (Pers.) Rostr.
Seedling blight	*Helminthosporium sativum* P. K & B.
Spot blotch	*Helminthosporium sativum* P. K. & B.
Glume blotch	*Septoria nodorum* Berk.
Speckled leaf blotch	*Septoria Tritici* Desm.
Ergot	*Claviceps purpurea* (Fr.) Tul.
Bacterial black chaff	*Xanthomonas translucens* (J. J. & R.) Dowson amend. Hagb. f. sp. *undulosa* (S. J. & R.) Hagb. and f. sp. *cerealis* Hagb.
Basal glume blotch	*Pseudomonas atrofaciens* McCull.
Oats	
Covered smut	*Ustilago levis* (Kell. & Sw.) Magn.
Loose smut	*Ustilago Avenae* (Pers.) Jens.
Seedling blight	*Helminthosporium sativum* P. K. & B. and *Fusarium* spp.
Leaf blotch	*Helminthosporium Avenae* Eidam
Halo blight	*Pseudomonas coronafaciens* (Elliott) Stev.
Barley	
Covered smut	*Ustilago Hordei* (Pers.) Lagerh.
Loose smut	*Ustilago nuda* (Jens.) Kell. & Sw.
False loose smut	*Ustilago nigra* Tapke
Seedling blight	*Helminthosporium sativum* P. K. & B.
Spot blotch	*Helminthosporium sativum* P. K. & B.
Net blotch	*Helminthosporium teres* Sacc.
Septoria leaf blotch	*Septoria Passerinii* Sacc.
Ergot	*Claviceps purpurea* (Fr.) Tul.
Bacterial blight	*Xanthomonas translucens* f. sp. *hordei* Hagb. and f. sp. *hordei-avenae* Hagb.
Basal glume blotch	*Pseudomonas atrofaciens* McCull.
Rye	
Seedling blight	*Helminthosporium sativum* P. K. & B.
Ergot	*Claviceps purpurea* (Fr.) Tul.
Speckled leaf blotch	*Septoria Secalis* Prill. & Del.
Bacterial blight	*Xanthomonas translucens* f. sp. *secalis* (R. G. & J.) Hagb. and f. sp. *undulosa*

With the exception of ergot (*Claviceps purpurea*), the pathogens responsible for the diseases listed in Table 1 are carried either on the surface of the seed or within the seed. Some of these are distributed wholly in this way, while others may be transmitted in a number of additional ways. The fungus that causes ergot produces hard, horn-like bodies, called sclerotia, in the heads of diseased cereal plants. These bodies are carried with the seed but not attached to it. Ergot attacks rye chiefly, but also barley and wheat, and sometimes oats. Only an occasional sample of seed examined in the present investigation contained ergot bodies.

TABLE 2.—PERCENTAGE OF KERNELS INFECTED WITH *Helminthosporium* SPP., *Fusarium* SPP., AND OTHER FUNGI IN SAMPLES OF WHEAT, OAT, BARLEY, AND RYE SEED FROM THE CROPS OF 1937 TO 1942 IN MANITOBA

Kind of seed and year produced	Number of seed samples examined	Mean percentage of kernels infected with:*						Percentage of kernels fungus-free
		Helminthosporium spp.			*Fusarium* spp†	*Alternaria* spp.	Other fungi‡	
		sativum	*Avenae*	*teres*				
WHEAT								
1937	102	5.4		—	0.6	69.2	1.7	25.6
1938	290	4.4		—	0.4	74.3	1.7	20.8
1939	360	2.3	—		0.4	57.7	4.6	36.4
1940	390	2.9	—	—	1.0	71.7	2.4	23.8
1941	390	5.6	—	—	0.8	76.4	4.5	16.2
1942	178	4.8		—	0.9	76.7	2.8	16.9
1937–42	1710	3.5	—	—	0.6	70.2	3.2	23.9
OATS								
1940	127	1.2	0.6	—	1.1	51.6	3.1	44.2
1941	260	3.6	1.0		3.0	77.6	9.9	16.6
1942	131	2.6	0.7	—	2.0	72.1	3.7	23.9
1940–42	518	2.7	0.8		2.3	69.8	6.6	25.2
BARLEY								
1937	60	9.8	—	3.5	1.1	85.7	3.0	7.5
1938	60	7.6	—	1.3	1.7	89.0	4.3	6.4
1939	130	2.7		3.2	0.9	59.9	6.5	29.6
1940	219	3.4		3.1	1.4	81.7	3.3	12.1
1941	260	7.7	—	2.6	1.3	83.0	5.7	10.2
1942	161	5.2	—	2.2	1.8	80.8	2.5	13.3
1937–42	890	5.5	—	2.7	1.4	80.0	4.2	13.6
RYE								
1939–42	50	3.9		—	1.3	73.9	8.6	20.8

* Based on the results obtained by plating out 100 surface sterilized kernels of each sample on potato dextrose agar in Petri dishes.
† Chiefly *Fusarium Poae*, *F. Scirpi* v. *acuminatum*, and *F. Equiseti*.
‡ Species of *Nigrospora*, *Curvularia*, *Cladosporium*, *Epicoccum*, *Septoria*, *Cephalothecium*, *Stemphylium*, *Pullularia*, *Penicillium*, and many other genera.

All the bacterial diseases of cereals known to occur in Manitoba are seed-borne[4]. Some of these, particularly halo blight of oats and black chaff of wheat, are common almost every year, and in certain seasons cause

[4] The writers are indebted to Dr. W. A. F. Hagborg, Dominion Laboratory of Plant Pathology, Winnipeg, Man., for information concerning the occurrence of bacterial diseases of cereals in Manitoba.

TABLE 3.—THE PREVALENCE IN MANITOBA OF *Helminthosporium sativum*, *H. Avenae*, *H. teres*, AND *Fusarium* SPP. IN SAMPLES OF WHEAT, OAT, AND BARLEY SEED FROM THE CROPS OF 1937 TO 1942

Kind of seed and year produced	Number of samples examined	*Helminthosporium sativum*		*Helminthosporium* spp.*		*Fusarium* spp.	
		Percentage of samples infected	Maximum percentage of kernels infected†	Percentage of samples infected	Maximum percentage of kernels infected†	Percentage of samples infected	Maximum percentage of kernels infected†
WHEAT							
1937	102	94	15	—	—	39	2
1938	290	87	29	—	—	27	3
1939	360	68	19	—	—	28	6
1940	390	85	24	—	—	56	25
1941	390	95	40	—	—	48	8
1942	178	91	50	—	—	54	7
1937–42	1710	84.2	50	—	—	41.0	25
OATS							
1940	127	62	5	41	9	50	20
1941	260	90	46	40	25	62	67
1942	131	77	26	31	15	60	24
1940–42	518	80.1	46	38.1	25	58.7	67
BARLEY							
1937	60	100	95	83	19	57	9
1938	60	93	44	43	15	68	9
1939	130	73	56	65	49	51	5
1940	219	87	27	59	29	46	20
1941	260	96	38	66	33	54	16
1942	161	87	33	57	22	71	12
1937–42	890	88.8	95	62.4	49	56.0	20

* *Helminthosporium Avenae* in oats, and *H. teres* in barley.
† Highest percentage of kernels infected in any sample.

appreciable loss. Unfortunately, no satisfactory method of detecting the presence of bacterial diseases in cereal seed has been developed. For this reason the studies reported in this paper deal mainly with the seed-borne diseases caused by fungi.

FUNGI ASSOCIATED WITH CEREAL SEED

The internal fungus flora of 3168 samples of cereal seed was determined by the plating method already described. The relative frequency of isolation of certain disease-producing, and other fungi, is given in Table 2. Fungi belonging to more than 60 genera were isolated. Those of most common occurrence belonged to the following genera. *Alternaria*, *Helminthosporium*, *Fusarium*, *Nigrospora*, *Curvularia*, *Epicoccum*, *Cephalothecium*, *Septoria*, *Pullularia*, *Cladosporium*, *Stemphylium*, *Penicillium*, *Aspergillus*, and *Mucor*. Several species of bacteria, yeasts, and actinomycetes were also isolated, but no distinctly pathogenic forms of these organisms were found.

As shown in Table 2, species of *Alternaria* were the predominant fungi. In the samples of wheat, oat, barley, and rye seed examined from 1937 to 1942, the average percentage of seeds infected with such species was, respectively, 70.2, 69.8, 80.0, and 73.9%. However, the writers (11) have shown that, although *Alternaria* spp. are commonly associated with Manitoba-grown cereal seed, and cause a discoloration of the kernel in wheat, barley, and rye, they are not responsible for seedling blight or leaf spot in the subsequent seedling stands. Thus, from a seed-borne disease standpoint, the presence of these fungi in such seed is not considered important.

Among the many other fungi isolated, the predominating pathogenic species were *Helminthosporium sativum* from wheat, barley, and rye; *H. Avenae* from oats; and *H. teres* from barley. Particular attention was paid to the isolation of these fungi, and the results of the soil infection tests, presented later in this paper, deal mostly with them. The prevalence of these fungi in samples examined from 1937 to 1942 is shown in Table 3.

It will be seen from Table 3 that *H. sativum* was present in 84.2% of the wheat, and in 88.8% of the barley samples. Although this fungus was found in 80.1% of the oat samples examined, it is not generally considered an important seed-borne pathogen of this crop. As might be expected, marked differences in the various crop samples occurred in respect to the amount of seed infection with *H. sativum*. In wheat, the infection range in the various samples was from 1 to 50%, and in barley from 1 to 95%.

In order to obtain a true picture of the importance of *H. sativum* in the samples, it is necessary to examine the frequency with which this fungus was isolated from individual kernels of the infected samples. It was found that an average of 3.5% of the wheat and 5.5% of the barley kernels cultured from 1937 to 1942 harboured this fungus. The average amount of kernel infection in rye and oat seed was, respectively, 3.9 and 2.7% (Table 2). It is evident that in Manitoba barley seed is always more heavily infected with *H. sativum* than is wheat seed, while oat seed carries the least infection.

H. sativum was widely distributed in Manitoba. The amount of infection in seed from the 12 major crop districts of the province is given in Table 4. As the data in this table show, wide differences occurred in the percentage of kernels infected with this fungus in different districts.

In the present study, the relation between the occurrence of seed infection by *H. sativum* and the normal rainfall during the growing season was given consideration. Rainfall data compiled by the Meteorological Division, Air Services of Canada, Winnipeg, Manitoba show that the normal rainfall during the period April 1 to September 9 at Brandon (Crop district 8), Portage la Prairie (Crop district 3N), Pierson (Crop district 1), and Russell (Crop district 10) was, respectively, 11.41, 11.12, 10.73, and 10.55 inches. The corresponding mean percentage figures for barley seeds infected with *H. sativum* were, respectively, 5.9, 7.4, 3.3, and 3.0% (Table 4). It is evident, therefore, that the heaviest seed infection occurred in districts with the highest rainfall during the growing season. This finding is in agreement with observations made in Manitoba over a long period of time and shows that severe infection of cereal seed with pathogenic fungi usually occurs in districts with the highest rainfall during the growing season.

TABLE 4.—THE FREQUENCY OF ISOLATION OF *Helminthosporium sativum*, *H. Avenae*, *H. teres*, AND *Fusarium* SPP. FROM WHEAT, OAT, AND BARLEY SEED PRODUCED IN DIFFERENT CROP DISTRICTS OF MANITOBA IN 1939, 1940, 1941, AND 1942

Crop district*	Mean percentage of kernels infected with:†							
	Helminthosporium sativum			*Fusarium* spp.			*Helminthosporium* spp.	
							H. Avenae	*H. teres*
	Wheat (95)‡	Oats (40)	Barley (60)	Wheat (95)	Oats (40)	Barley (60)	Oats (40)	Barley (60)
1. Melita	1.8	2.0	3.3	0.8	4.4	1.2	0.3	2.9
2. Killarney	2.8	2.3	4.5	0.8	3.1	1.8	0.3	2.0
3. Red River (S)	3.2	2.7	5.8	0.7	2.4	0.7	0.9	3.6
3. Red River (N)	4.6	3.6	7.4	0.7	1.3	1.3	0.8	3.8
4. Winnipeg	4.3	3.7	5.9	0.7	2.0	0.5	0.5	2.9
5. Springfield	4.7	3.2	4.6	0.6	0.6	0.6	0.7	3.4
6. Eastern	3.7	5.0	7.7	0.4	2.7	1.2	0.8	2.7
7. Virden	4.0	1.8	5.6	0.8	2.4	2.4	0.5	2.2
8. Carberry	4.5	2.2	5.9	1.0	1.8	0.9	0.7	2.9
9. Neepawa	5.0	2.3	4.5	1.0	2.2	1.3	0.6	2.7
10. Russell	2.9	1.8	3.0	1.4	1.9	3.0	1.0	2.2
11. Dauphin	4.5	3.0	4.2	0.5	0.6	1.0	1.8	2.5
13. Swan River	4.4	2.1	4.1	0.7	2.9	1.8	1.8	4.6

* Manitoba crop reporting district (see Figure 1). S = South, N = North.
† Based on the results obtained by plating out 100 surface-sterilized kernels of each sample on potato dextrose agar in Petri dishes.
‡ Approximate number of samples examined per crop district.

The average percentage of kernels infected with the leaf blotch fungus (*Helminthosporium Avenae*) in the 518 samples of oats examined was less than 1% (Table 2), while the maximum percentage in any sample was 25%. Nevertheless, this pathogen was harboured in 38.1% of the samples (Table 3). Internal infection of the kernels varied widely from district to district. The most severe infections of this type occurred in the cooler northern crop districts of Manitoba, namely, Dauphin and Swan River (Table 4). Additional plating tests with a large number of the samples of oat seed indicated that in certain samples infection of the kernels with *H. Avenae* was quite superficial, so that the organism was destroyed when the kernels were surface sterilized prior to being plated out. It must, therefore, be assumed that percentages of infection with *H. Avenae* higher than those recorded in Tables 2, 3, and 4 occurred in the oat samples.

An examination of 819 samples of seed barley collected from 1937 to 1942 showed that 62.4% of them carried the net blotch fungus (*Helminthosporium teres*). The maximum percentage of kernels infected in any sample was 49% (Table 3), whereas the average percentage in all samples was only 2.7% (Table 2). Generally speaking, barley seed produced in northern Manitoba (Swan River) was more heavily infected with *H. teres* than was that produced in other districts of the province (Table 4).

The frequency of isolation of species of *Fusarium* from the seed of wheat, oats, and barley from different crop districts is shown in Table 4. Obviously, these fungi are widely distributed on seed in Manitoba. Oat seed was more severely infected than was the seed of wheat or barley. In oats, the most severe seed infection occurred in the drier crop districts of the province, namely, Melita and Killarney.

In the present study, *Fusarium* spp., one or more, were isolated from 41.0% of the wheat samples, 58.7% of the oat samples, and 56.0% of the barley samples (Table 3). Although present in a fairly large proportion of the samples, *Fusarium* spp. were isolated from only a small percentage of the kernels. The average amount of infection in 1710 samples of wheat, 518 samples of oats, 890 samples of barley, and 50 samples of rye was, respectively, 0.6, 2.3, 1.4, and 1.3% (Table 2), while the highest percentage of kernels infected in any sample of wheat, oats, and barley, was, respectively, 25, 67, and 20% (Table 3).

Of a total of 16 species, varieties, or forms of *Fusarium* isolated, *Fusarium Poae*, *F. Equiseti*, and *F. Scirpi* var. *acuminatum* were the predominant species. The well-known pathogenic species *Fusarium culmorum* and *F. graminearum* were by no means commonly isolated. *F. culmorum* was isolated from only 16 out of 1710 samples of wheat, from 3 out of 518 samples of oats, and from 8 out of 890 samples of barley; while *F. graminearum* was isolated from 7 samples of wheat, 2 of oats, and 2 of barley. Most of the other species isolated are usually considered to be either non-pathogenic or only feebly pathogenic to cereals (8). Gordon (4) has given an account of the species of *Fusarium* commonly associated with cereal seed in Manitoba.

Beside the fungi already mentioned, certain species of *Septoria* pathogenic to cereal seedlings were isolated from the seed of wheat, oats, and barley. They were obtained most frequently from wheat, and least frequently from oat seed. Although the amount of injury from seed-borne *Septoria* spp. is relatively small in Manitoba, there is no guarantee that these species will always remain unimportant in this province. A report on the prevalence and importance of species of *Septoria* on cereal seed in Canada has been published by Machacek (10).

Relation of *Helminthosporium sativum* in Wheat and Barley Seed to Emergence and Seedling Blight

With a view to determining the relation between the percentage of seeds infected with *Helminthosporium sativum* and the amount of disease subsequently developing in the seedlings, the results of agar-plate and soil tests with 1481 samples of wheat and 747 barley samples from the crops of 1939, 1940, 1941, and 1942 were compared. The results of these comparisons are summarized in Table 5.

TABLE 5.—PERCENTAGE OF WHEAT AND BARLEY KERNELS INFECTED WITH *Helminthosporium sativum* IN RELATION TO THE PERCENTAGE OF KERNELS GERMINATING AND THE PERCENTAGE OF LESIONED SEEDLINGS. RESULTS OF AGAR-PLATE AND NON-STERILE SOIL TESTS WITH SEED SAMPLES FROM THE CROPS OF 1939, 1940, 1941, AND 1942 IN MANITOBA

Kind of seed and infection class	Percentage of kernels infected with *H. sativum**	Samples per class		Mean percentage plant emergence†	Mean percentage of seedlings with basal lesions†
		Number	Per cent		
WHEAT					
I	0 – 4	1047	70.7	92.2	2.4
II	5 – 9	303	20.5	89.9	6.9
III	10 – 14	87	5.9	88.0	10.3
IV	15 – 19	28	1.9	86.1	12.4
V	20 +	16	1.0	82.9	18.9
BARLEY					
I	0 – 4	455	60.9	93.4	1.4
II	5 – 9	172	23.0	94.4	2.2
III	10 – 14	81	10.9	89.2	3.9
IV	15 – 19	24	3.2	92.6	5.3
V	20 +	15	2.0	93.2	14.5

* As determined by agar-plate test with 100 surface-sterilized kernels of each sample.
† Results of infection tests in non-sterile soil with 100 kernels of each sample.

The data in Table 5 show that the percentage of wheat and barley seeds found by the agar-plate test to be infected with *H. sativum* was closely related to the percentage of seedlings with basal lesions when the seed was sown in non-sterile soil. An increase in the amount of seed infection was always accompanied by an increase in the percentage of blighted seedlings. Significant positive correlation coefficients of + 0.775 and + 0.841 were obtained for the data of the wheat and barley samples, respectively. These results confirm those of Christensen and Stakman (2), who found that the amount of seedling blight in barley was directly proportional to the percentage of seeds infected with *Helminthosporium* species, mostly *H. sativum.*

In barley, but not in wheat, there was a marked tendency for the percentage of seed infection to be higher than the percentage of seedlings with basal lesions. This difference was due, no doubt, to the fact that some lots of barley were infected with non-pathogenic or only weakly pathogenic strains of *H. sativum.* These results with barley emphasize the importance, in ascertaining the state of health of the seed of various cereal crops, of determining the relative prevalence of pathogenic and non-pathogenic strains of *H. sativum,* and of other fungi, in the seed.

As shown in Table 5, an increase in the percentage of wheat kernels infected with *H. sativum* was accompanied by a decrease in the percentage of seedling emergence. When the emergence and seed infection data were studied statistically, a significant negative correlation coefficient of −0.521 was obtained. These results indicate that seed-borne *H. sativum* is responsible for considerable pre-emergence blight in wheat. In barley, however, no significant difference in emergence was found between relatively

clean lots of seed (0 to 4% infection) and heavily infected samples (more than 14% infection). Thus, in barley, percentage emergence is not a reliable index of the degree of seed infection by *H. sativum*, and hence of the value of a sample for seeding purposes. The health condition of the seedlings arising from barley seed also must be taken into consideration.

With regard to the intensity of seed infection, the data of Table 5 show that in 91.2% of the wheat samples, and in 83.9% of those of barley tested, less than 10% of the seeds were infected by *H. sativum*. On the other hand, only in 1% and 2% of the wheat and barley samples, respectively, was the percentage of seed infection 20% or more. These results indicate that a large proportion of the wheat and barley seed being produced and sown in Manitoba is only lightly infected with this pathogen. From the grower's point of view this is important. The practical significance of relatively light infections with *H. sativum* in wheat and barley seed has yet to be determined.

PREVALENCE OF SEEDLING-BLIGHT AND LEAF-SPOT FUNGI IN CEREAL SEED

To determine the amount of infection with the seedling-blight and leaf-spot fungi *Helminthosporium* spp., and probably *Fusarium* spp., in samples of wheat, oat, and barley seed, at least 100 seeds of each sample were planted in beds of non-sterile soil in the greenhouse. When the seedlings were 12 to 14 days old (second leaf stage) they were lifted from the soil, cleaned, counted, and examined for basal and leaf lesions. The percentage of seedlings with such lesions was used as an index of the health condition of each seed lot. The non-sterile soil test used in the present studies was that developed and employed by Machacek and Wallace (13).

On the basis of the soil test, the samples of wheat and oat seed were separated into 2 groups, one in which 5% or more of the seeds produced seedlings with basal lesions (diseased samples), and the other in which less than 5% of the seeds produced lesioned seedlings (healthy samples). Owing to the fact that the soil test alone is apparently unreliable for the appraisal of the amount of seed infection in barley with *Helminthosporium teres* (13), the barley samples were classified on the basis of the results of 2 tests—an agar-plate test and a soil test. In determining the health condition of a sample, the percentage of seed found by the agar-plate test to be infected by *H. teres* was added to the percentage of seed found to be lesioned (*H. sativum* and *Fusarium* spp.) when the seed was planted in non-sterile soil. If the sum of these figures exceeded an arbitrary figure of 5% the sample was classified as diseased.

As the results in Table 6 show, the average percentage plant emergence for the healthy samples of wheat, oat, and barley seed tested was 93.9, 95.8, and 94.5%, respectively; whereas the average percentage emergence for the diseased samples was 89.1, 85.6, and 92.7%, respectively, Thus, the presence of more than 5% seed infection with species of *Helminthosporium* and *Fusarium* in samples of wheat and oat seed reduced the percentage of seedlings that emerged from the soil by 4.8 and 10.2%, respectively. In barley, no significant difference in emergence was found between relatively clean lots of seed and lots that carried more than 5% seed infection with *Helminthosporium sativum* and *H. teres*.

TABLE 6.—THE RELATION OF SEED INFECTION WITH SEEDLING-BLIGHT AND LEAF-SPOT FUNGI (SPECIES OF *Helminthosporium* AND *Fusarium*) TO PLANT EMERGENCE IN SAMPLES OF WHEAT, OAT, AND BARLEY SEED FROM THE CROPS OF 1937 TO 1942 IN MANITOBA

Kind of seed and year produced	Number of samples examined	Diseased samples*		Healthy samples†	
		Number	Per cent plant emergence	Number	Per cent plant emergence
WHEAT					
1937	97	83	85.8	14	92.8
1938	88	44	91.9	44	94.4
1939	360	66	92.5	294	95.6
1940	390	66	91.1	324	91.5
1941	390	122	88.4	268	95.2
1942	151	35	85.4	116	93.3
1937–42	1476	416	89.1	1060	93.9
OATS					
1940	127	46	84.2	81	96.8
1941	260	23	86.6	237	95.5
1942	131	11	89.1	120	95.6
1940–42	518	80	85.6	438	95.8
BARLEY					
1937	60	56	88.4	4	90.0
1938	59	36	95.2	23	97.7
1939	130	11	96.7	119	95.8
1940	219	13	97.1	205	96.0
1941	260	25	92.9	235	92.6
1942	138	42	93.5	97	94.2
1937–42	866	183	92.7	683	94.5

* Samples in which 5% or more of the seeds, when planted in non-sterile soil, produced diseased seedlings.
† Samples in which less than 5% of the seeds produced diseased seedlings.

The prevalence of seedling disease caused by species of *Helminthosporium* and *Fusarium* in samples of wheat, oat, and barley seed examined in the course of the survey is shown in Table 7. According to the soil test 28% of the 1476 wheat samples, 15% of the 518 oat samples, and 40% of the 866 barley samples were diseased, while the average percentage of seedlings infected in these sets of samples was 9.4, 8.4, and 14.0%, respectively. These results indicate that in certain years a considerable amount of the seed of wheat, oats and barley that is produced in Manitoba is relatively free of seedling-blight and leaf-spot fungi, while in other years a high percentage of the seed may be severely infected with these disease-producing organisms. Observations made over a period of years have indicated that in Manitoba severe infection of cereal seed with these pathogens is usually associated with wet years, and more particularly with years in which wet weather prevails during the later part of the growing period.

In the course of the investigation the seed of several varieties of wheat, oats, and barley was examined for the presence of disease-producing fungi. It was found that some varieties were more susceptible to internal seed

TABLE 7.—PREVALENCE IN MANITOBA OF SEEDLING BLIGHT AND CERTAIN LEAF SPOTS CAUSED BY SPECIES OF *Helminthosporium* AND *Fusarium* IN SAMPLES OF WHEAT, OAT, AND BARLEY SEED FROM THE CROPS OF 1937 TO 1942

Kind of seed and year produced	Number of samples examined	Percentage of samples diseased*	Mean percentage of seedlings infected
WHEAT			
1937	97	83	15.1
1938	88	50	10.4
1939	360	18	7.3
1940	390	17	6.7
1941	390	32	8.2
1942	151	23	7.9
1937–42	1476	28	9.4
OATS			
1940	127	36	9.8
1941	260	9	6.5
1942	131	8	7.0
1940–42	518	15	8.4
BARLEY			
1937	60	98	20.4
1938	59	68	14.4
1939	130	32	9.7
1940	219	29	6.5
1941	260	33	8.3
1942	138	47	11.9
1937–42	866	40	14.0

* Samples in which 5% or more of the seeds, when planted in non-sterile soil, produced diseased seedlings. In barley the figures represent samples in which 5% or more of the seeds produced diseased seedlings and/or were infected with *Helminthosporium teres*.

infection by these fungi than were others. Thus, the variety grown may be an important factor affecting the prevalence of seed-borne diseases in Manitoba.

No attempt is made here to record the prevalence of retarded, stunted, deformed, or weak seedlings in the samples tested, or to discuss the probable causes of these troubles. The importance of such seedling abnormalities in the appraisal of cereal seed for seed purposes is fully realized, but a discussion of them lies outside the scope of this paper.

PREVALENCE OF SURFACE-BORNE SMUT IN SAMPLES OF CEREAL SEED

Samples of wheat and barley seed from the crops of 1939 to 1942, inclusive, and of oat samples from the crops of 1940, 1941, and 1942 were examined for the presence of smut. The present survey, however, deals only with those cereal smuts that are carried on the surface of the seed. They are as follows: bunt (covered smut of wheat), covered smut of barley, false loose smut of barley, covered smut of oats, and loose smut of oats. Although some progress has been made in developing a suitable technique for determining the presence of the loose smut fungi *Ustilago Tritici* and *U. nuda* in wheat and barley seed, respectively, no satisfactory practical

procedure is at present available. Here it may be mentioned that, although the loose smuts of wheat and barley are widely distributed in Manitoba, the annual loses to this province through them is considerably less than those caused by the surface-borne smuts (3).

TABLE 8.—PREVALENCE IN MANITOBA OF SURFACE-BORNE SMUT IN FARM SAMPLES OF WHEAT, OAT, AND BARLEY SEED FROM THE CROPS OF 1939, 1940, 1941, AND 1942

Kind of seed and year produced	Number of samples examined	Percentage of samples carrying:		
		Smut spores	Light smut-spore load*	Heavy smut-spore load†
WHEAT				
1939	360	46.1	44.2	1.9
1940	390	55.1	54.6	0.5
1941	390	78.9	73.5	5.4
1942	151	45.0	38.4	6.6
1939–42	1291	58.6	55.2	3.4
OATS				
1940	127	99.2	41.7	57.5
1941	260	100.0	14.6	85.4
1942	131	99.2	24.4	74.8
1940–42	518	99.6	23.7	75.9
BARLEY				
1939	130	100.0	46.2	53.8
1940	219	100.0	22.5	77.5
1941	260	100.0	21.9	78.1
1942	138	100.0	26.8	73 2
1939–42	747	100.0	27.3	72.7

* Spore load less than 1 : 128,000, by weight.
† Spore load at least 1 : 128,000, by weight. Seed treatment recommended.

The prevalence of the surface-borne smuts in the samples of wheat, oat, and barley seed examined in the course of the survey is shown in Table 8. Determinations of the smut spore loads present on the seed indicated that 58.6% of the wheat samples carried spores of bunt (*Tilletia laevis* and *T. Tritici*), 99.6% of the oat samples carried spores of covered smut and loose smut (*Ustilago Avenae* and *U. levis*), and 100% of the barley samples examined carried spores of the surface-borne smuts *Ustilago Hordei* and *U. nigra*. A point of greater importance is that the spore load was high enough on 3.4% of the wheat samples, 75.9% of the oat samples, and 72.7% of the barley samples, to make seed treatment for smut control seem necessary.

Spores of many different fungi were observed in the washings of samples of wheat, oat, and barley seed. In addition to those of smut fungi, spores of the following genera were of most frequent occurrence: *Alternaria*, *Helminthosporium*, *Fusarium*, *Epicoccum*, *Cladosporium*, *Puccinia*, *Penicillium*, *Aspergillus*, and *Mucor*. Bacteria, yeasts, and actinomycetes were also prevalent. For the most part the species of fungi observed were representative of the types commonly isolated from surface-sterilized cereal seeds (Table 2), and from soils in Manitoba (9).

Summary of Pathological Seed Tests

The results of the various pathological tests just presented for samples of wheat, oat, and barley seed from the crops of 1939, 1940, 1941, and 1942 in Manitoba are summarized in Table 9. On the basis of these tests the samples were separated into two classes, namely, diseased and healthy. In the diseased samples seed infection with surface-borne smut, or with other disease-producing fungi, was sufficiently heavy to necessitate seed treatment. As might be expected, and as the results in Table 9 show, many seed lots carried not only a smut load of that amount, but were infected to a dangerous degree with other disease-producing fungi as well. In the healthy samples, the seed was virtually free of smut and other disease-producing organisms. These samples were further sub-divided into those that germinated poorly (less than 91%) and those that germinated well (91% or above) in non-sterile soil. The germination of many of the former samples was not improved by seed treatment, and, consequently, they could not be considered entirely suitable for seeding purposes. In reporting on the health condition of the low-germinating samples to the growers concerned, an increase in rate of seeding was recommended.

Table 9.—Summary of tests made to determine the state of health of farm samples of wheat, oat, and barley seed from the crops of 1939, 1940, 1941, and 1942 in Manitoba

Kind of seed and year produced	Number of samples examined	Percentage of samples examined					
		Diseased*			Healthy†		
		Surface-borne smut	Seedling blight and leaf spots	Total	Seed of low germinability‡	Seed of high germinability*	Total
Wheat							
1939	360	1 9	18 3	18.3	18.9	62.8	81.7
1940	390	0.5	16 9	17.7	27.4	54.9	82.3
1941	390	5.4	31.8	35.4	21 3	43.3	64.6
1942	151	6.6	23.2	29.1	30 5	40.4	70.9
1939–42	1291	3.3	22.5	24.7	23.5	51.8	75.3
Oats							
1940	127	57.5	35.9	73.2	4.7	22.1	26.8
1941	260	85.4	8.8	88.1	6.5	5.4	11.9
1942	131	74.8	8.3	76.3	3.1	20.6	23.7
1940–42	518	75.9	15.4	81.5	5 2	13.3	18.5
Barley							
1939	130	53.8	31.5	66.2	1.5	32 3	33.8
1940	219	77.5	28.8	83.6	0.9	15.5	16.4
1941	260	78.1	33.3	81.9	6.6	11.5	18.1
1942	138	73.2	47.1	84.1	2.9	13.0	15.9
1939–42	747	72.7	34.3	80.1	3 3	16 6	19.9

* Samples in which infection with surface-borne smut, or with other disease-producing fungi, was sufficiently high to necessitate seed treatment. The seed of some of these samples was also of low germinability, and, consequently, increase in rate of seeding and seed treatment were recommended to the growers concerned.

† Samples virtually free of disease-producing fungi.

‡ Percentage germination less than 91%. Germination not improved by seed treatment. Increase in rate of seeding recommended to the growers concerned.

§ Percentage germination 91% or more.

The data in Table 9 show that, on the basis of the arbitrary standards used, 24.7% of the seed samples of wheat, and more than 80% of the samples of oats and of barley examined required seed treatment for disease control. It is obvious, therefore, that a large proportion of the cereal seed used in Manitoba in 1940, 1941, 1942, and 1943 was not suitable for seed purposes. The results of the present survey support the view that all farmers in Manitoba should subject their cereal seed, particularly their oat and barley seed, to surface disinfection, unless it has been found by proper examination to be free from disease-producing organisms.

Control of Seedling Blight and Certain Leaf Spots of Cereals by Seed Treatment

In the course of the present seed-borne disease investigation, seed treatment tests were made with a large number of both diseased and healthy samples of wheat, oat, and barley seed. For these tests, two 100-kernel lots were taken at random from each seed sample. One of these was treated with a dust disinfectant consisting of one part of Ceresan (5% ethyl mercury phosphate) to two parts of talc. To insure complete coverage of each kernel the dust was applied in excess. The second 100-kernel lot remained untreated. The treated and untreated lots were planted in adjacent rows in beds of non-sterile soil in the greenhouse, and notes were taken when the seedlings were in the 2-leaf stage. The results are given in Table 10.

The data for the diseased seed samples in Table 10 show that treatment of infected seed of wheat, oats, and barley with an organic mercury dust was consistently beneficial to emergence, and gave almost complete control of seedling blight and leaf spots caused by species of *Helminthosporium* and *Fusarium*. The higher the degree of seed infection the more beneficial was the treatment. Furthermore, it was found that lightly infected cereal seed, when properly treated with a mercury dust, was just as good for seeding purposes as was healthy seed. Of course, healthy seed is preferable if it is available, but unless the seed is known to be healthy treatment is recommended.

The mean percentage germination figures for the healthy seed samples of wheat, oats, and barley examined (Table 10), indicate that the germination of such samples was not increased significantly by seed treatment. This finding supports the view that there is little value in treating healthy seed of cereals, unless it is sown in heavily infested soil.

That it is a mistake to neglect treating even lightly infected seed of small grain crops is shown by the present greenhouse studies. The fact that a large proportion of the cereal seed produced and sown in Manitoba carries disease-producing organisms indicates that seed treatment should be more widely and consistently practised in this province. The results of the present greenhouse tests are in agreement with those found in extensive field trials in Manitoba (7, 11, 12), and show that some of the most destructive seed-borne diseases of cereals can be effectively controlled by seed treatment.

TABLE 10.—THE EFFECT OF TREATING DISEASED AND HEALTHY SAMPLES OF WHEAT, OAT, AND BARLEY SEED WITH CERESAN ON PLANT EMERGENCE, AND ON THE CONTROL OF SEEDLING BLIGHT AND CERTAIN LEAF SPOTS. (DATA ARE MEANS OF SAMPLES EXAMINED FROM THE CROPS OF 1939, 1940, 1941, AND 1942)

Kind and condition of seed	Number of samples examined	Percentage plant emergence			Percentage of seedlings diseased		
		Treated seed‡	Untreated seed§	Increase due to treatment	Treated seed‡	Untreated seed§	Increase due to treatment
WHEAT							
Diseased*	622	93.4	87.3	6.1	0.3	5.1	4.8
Healthy†	669	95.9	94.6	1.3	0.1	0.1	0.0
OATS							
Diseased	207	88.7	84.5	4.2	0.3	4.7	4.4
Healthy	311	96.0	95.9	0.1	0.2	0.3	0.1
BARLEY							
Diseased	213	91.3	88.1	3.2	0.1	5.0	4.9
Healthy	534	96.8	96.9	−0.1	0.1	0.3	0.2

* Seed samples in which less than 91% of the untreated seeds produced healthy seedlings.
† Seed samples in which 91% or more of the untreated seeds produced healthy seedlings.
‡ Seed dusted with dilute Ceresan (5% ethyl mercury phosphate).
§ Natural, untreated seed.

DISCUSSION

The standards used to determine the value of seed-grain for seeding purposes are based on purity of variety, freedom from weed seeds, and germination. Thus, high value is attached to the ability of the seed to germinate and produce strong plants. One of the most important factors influencing the germinability of cereal seed is the presence of disease-producing organisms in or on the seed. The present studies have indicated clearly that the presence of more than 5% kernel infection with these organisms markedly reduces the germination of wheat and oat seed. Furthermore, the planting of infected seed practically ensures the perpetuation of the disease. Infected seed carries the disease into areas where it did not previously exist. Unfortunately, much of the seed of wheat and oats and some of the barley seed that is produced and sown in Manitoba carries with it organisms that reduce germinability. Such seed is of inferior quality, and should be subjected to surface disinfection before it is used for seeding purposes.

The most important seed-borne diseases of small grain crops in Manitoba are the surface-borne smuts of oats and barley. Because of the marked prevalence of these diseases in this province, it is important that all practical means be employed to suppress them. Perhaps one of the most effective ways of doing this is to examine the seed for the presence of smut spores before it is used or sold for seeding purposes. Such an examination would indicate whether or not seed treatment could be employed with profit. Furthermore, if the seed was found to be free from smut its value for seeding purposes would be enhanced.

The grower, usually, is unable to distinguish between seed that carries disease and seed that does not. Testing seed for the presence of disease has to be done by qualified technicians in properly equipped laboratories. Unfortunately, the facilities needed to examine individual farmers' seed samples for smut, and other diseases, are not available. At the present time, the testing of cereal seed for the presence of disease parasites is confined to high-grade seed, that is, to stocks of Foundation, Elite, and Registered seed. The results presented in this report indicate that the establishment of a more adequate pathological seed service would constitute an important step forward in the interests of seed-borne disease control and of good seed production in Manitoba.

In view of the fact that 25% of the seed stocks of wheat and more than 80% of those of oats and of barley produced and sown in Manitoba have been found diseased, all farmers in this province would be well advised to treat their cereal seed each year as a routine practice. In other words, unless the seed is known to be healthy, treatment is strongly recommended. In addition to destroying seed-borne pathogens, seed treatment with an approved disinfectant may offer considerable protection against pathogenic organisms already present in the soil. Protection against these is only likely to be effective until shortly after the seed has germinated, but this is the critical period when such soil-inhabiting organisms are most likely to reduce germination and plant emergence. Seed treatment, in spite of the need for safer and better fungicides and for more efficient seed-treating machinery, seems to offer more practical and tangible results than any other procedure available for preventing the losses caused by seed-borne diseases of cereals in this province.

The examination of numerous samples of cereal seed from all the major crop districts of Manitoba has shown that each year a very large proportion of the samples carried disease-producing organisms (smut fungi, seedling-blight fungi, leaf-spot fungi, etc.). Not all Manitoba grown seed, however, carries seed-borne disease. As a rule, cereal seed produced in dry districts is less likely to be diseased than seed produced in wetter districts, but the variability of moisture is so great from season to season in any district that a distinction between dry and wet districts is too ill-defined to be applied in respect to the prevalence of seed-borne diseases.

Although the present seed studies have dealt almost entirely with seed-borne diseases of cereals caused by fungi, the importance of those of bacterial origin is fully recognized. However, further seed investigations are needed before the prevalence and importance of bacterial pathogens in cereal seed can be accurately determined. Another aspect of the cereal seed disease problem that has received far too little attention in this survey is that dealing with mechanical, frost, and other kinds of seed injury. The importance of these seed troubles in the production of grain for seed purposes is fully realized.

SUMMARY

With a view to ascertaining the state of health of the seed of wheat, oats, and barley being grown in Manitoba, more than 3000 farm samples of seed from the 1937 to 1942 crops from all over the province were examined.

Plating tests of the samples showed that several kinds of organisms, particularly fungi, were associated with much of the seed. Of the fungi isolated, *Helminthosporium sativum* on wheat, barley, and rye, *H. Avenae* on oats, and *H. teres* on barley were the predominating pathogens. Several species of *Fusarium* were frequently isolated, particularly from oat seed, most of which were either non-pathogenic or only feebly pathogenic to cereals. The well-known pathogenic species *Fusarium culmorum* and *F. graminearum* were by no means commonly isolated.

Extensive infection tests in non-sterile soil have indicated clearly that a close positive relationship exists between the percentage of wheat and of barley seeds infected by *H. sativum* and the occurrence of disease in the subsequent seedling stands. In wheat, but not in barley, seed infection with this fungus was associated with low germination.

Samples of cereal seed from the crops of 1939, 1940, 1941, and 1942 were examined for the presence of smut. Of the 1710 wheat samples examined, only 3.4% carried more than a trace of bunt (*Tilletia Tritici* and *T. laevis*). A total of 75.9% of the 518 samples of oats examined carried spores of loose and covered smut (*Ustilago Avenae* and *U. levis*) in sufficient amounts to make seed treatment necessary. The spore load of covered smut and false loose smut (*Ustilago Hordei* and *U. nigra*) on 72.7% of the 747 seed samples of barley examined was sufficiently heavy to necessitate seed treatment. These results indicate that seed treatment, particularly of oat and barley seed, is not being adequately carried out in Manitoba.

The amount of infection caused by smut fungi, seedling-blight fungi, and leaf-spot fungi on seed grain was found to vary appreciably from district to district, and from year to year, depending largely upon the particular environmental conditions under which the seed was produced. The survey indicated that some districts in Manitoba are more desirable for the production of healthy seed of cereals than are others.

Field observations made over a period of years in Manitoba have shown that, if climatic conditions favour early ripening and harvesting of cereal crops, the incidence of infection by seed pathogens is low; but, if warm humid weather occurs during ripening and harvesting, the incidence of infection is high. Another factor affecting the prevalence of seed infection with disease-producing organisms is the variety grown.

In greenhouse tests, treatment of a large number of infected samples of wheat, oat, and barley seed with an organic mercury dust gave almost complete control of seed-borne disease caused by species of *Helminthosporium* and *Fusarium*. Seed treatment improved the germination of infected wheat and oat seed, but it had little or no effect on the germination of healthy cereal seed. The treatment, therefore, of healthy seed is of little value unless the seed is sown in heavily infested soil.

The present survey shows that the health condition of the seed of wheat, oats, and barley being produced and used annually in Manitoba is by no means satisfactory. Almost 25% of the seed stocks of wheat and more than 80% of those of oats and of barley examined from the crops of 1939, 1940, 1941, and 1942 carried disease-producing organisms in sufficient amounts to necessitate seed treatment.

The most important seed-borne diseases of cereals in Manitoba are the surface-borne smuts of oats and barley. In the absence of adequate facilities for determining whether or not individual farmers' seed stocks of oats and barley are free from smut, and other diseases, it is strongly recommended that all seed of these crops produced in Manitoba should be treated with an approved disinfectant before it is sown.

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CLIMATIC FACTORS AFFECTING CROP PRODUCTION

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The settlement of Northern areas is largely dependent on the climatic conditions encountered. The weather not only determines the choice of crops to be grown but it also dictates how these crops are to be handled.

The Dominion Experimental Station at Beaverlodge has on record perhaps the largest body of meteorological data of any of the Northern Stations, and is situated on what might be regarded as the Southern fringe of Northern agriculture. For this reason the Beaverlodge data will be used to a considerable extent in this survey.

Precipitation

Precipitation records are available at Beaverlodge for 29 years. The average annual precipitation is 17.43 inches, 6 inches coming in the form of snow. The average monthly winter distribution is fairly regular, while spring opens with 0.80 inch of moisture in April. May precipitation amounts to 1.56 inches, June 2.11 inches and July 2.29 inches. Commencing with August the amount drops from 1.85 inches in that month to 1.15 inches in October. It is significant that in the 29-year period the April to August precipitation falls below 7 inches in 8 years and is in excess of 10 inches in 6 years.

By comparison Lacombe reports slightly less annual precipitation than Beaverlodge, with 3.3 inches coming in the winter months and 11.6 inches in the open season. The extra 3 inches of summer precipitation comes at a very opportune time.

At Fort Vermilion the annual precipitation is 11.90 inches, 7 inches of it coming in the summer months. At Norman, on the Mackenzie, the summer precipitation is about 6 inches, and beyond the Arctic circle it runs from 4.5 to 5 inches.

Evaporation

Records of evaporation from a free-water surface are available at Beaverlodge for 23 years. For the most part the tank was in operation from about April 20 to the end of October. The average yearly evaporation is 18.44 inches but in individual seasons it ranges from 11 to 22 inches. For the period during which the tank was in operation the precipitation averaged 11.12 inches or 7.32 inches less moisture than was evaporated from a free-water surface. The evaporation-precipitation ratio was lowest in the wet summer of 1935 and highest in the dry summer of 1922. By months, there was rather more evaporation in July than in May, June, or August, with a definite decrease in September and a further decrease in October.

While the May to September evaporation at Beaverlodge, in a 21-year average is 16.93 inches it is reported as being 15.39 inches at Lacombe, 24.60 inches at Lethbridge, and 33.17 inches at Manyberries for about the same period.

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Air Temperature

There is very little difference in the reported mean annual temperature at Beaverlodge and Lacombe. The Beaverlodge mean of 35.6 degrees is actually higher than that recorded at points in Manitoba and Saskatchewan with the exception of Morden and Swift Current. This condition results, however, from the December to March average at Beaverlodge being 13.9 degrees, while six Manitoba and Saskatchewan points average 6.4 degrees. The Beaverlodge average for April is slightly in excess of that of Melfort and Scott. The May mean stands at 47.9 degrees at Fort Vermilion, 49.1 degrees at Beaverlodge and 52.2 and 53.3 degrees at Swift Current and Manyberries, respectively. In June, Beaverlodge averages 55.5 degrees, Fort Vermilion 55.9 degrees, Lacombe 56.1 degrees and Manyberries 60.4 degrees. July temperatures average about 5 degrees higher throughout, followed by a decrease in August. In September the readings are about the same at all points as in May. The Beaverlodge readings are taken on a hillside which accounts for some modification as compared with ruling temperatures of the region.

Soil Temperature

The soil temperature at 3 inches drops to 24.36 degrees in January. In February it climbs to 25.12 degrees, in March to 27.73 degrees, in April to 35.42 degrees and in May to 48.31 degrees. In June it averages 56.79 degrees, in July 62.11 degrees and in August 59.25 degrees. Thus it is well into May before soil temperatures are sufficiently high to permit nitrification.

Sunshine

Beaverlodge enjoys 2103 hours of bright sunshine per year. Fort Vermilion has slightly less, 2093 hours, while Lacombe has 2170 and Lethbridge 2348 hours. A trend such as this seems reasonable, but its harmony is challenged by the Swift Current total of 2095 hours. Beaverlodge sunshine, as registered, is comparatively low until April, when it averages about 6 hours more than does Lacombe. In May the spread is increased to 26 hours, while in June it is 8 hours less than at Lacombe. In July the record is even, after which Lacombe is in the lead. At Fort Vermilion, however, the August sunshine is still in excess of that of Lacombe. It is known, however, that many hours of dull light are not recorded, which limits the value of these readings. In final analysis we must observe the reaction of plant growth to the sunlight to get the full meaning of this factor. Some data are available but many more will be needed before the North can be cropped to full advantage.

Wind

The average wind velocity at Beaverlodge is 8.3 miles per hour. This ranges from about 7 miles in the winter months to a peak of 10.5 miles in May. This is unfortunate as spring-sown crops are then vulnerable and provide the least cover. The highest wind velocity recorded at Beaverlodge is 48 miles per hour. Some rather serious soil drifting has occurred where preventive measures have not been taken.

DISCUSSION

On the Beaverlodge Station Marquis wheat, on fallow, has averaged 36.5 bushels per acre over a 30-year period. On the other hand Grimm alfalfa makes an average of $1\frac{1}{2}$ tons per acre from the one cutting usually taken. There is usually ample surface moisture for seeding, followed by a period rather unfavourable for growth. Plants which have become established develop a strong root system in this period, which serves in good stead later. Late-sown crops or crops sown on land where moisture-saving practices have not been followed may not do so well. June is sometimes dry and too frequently September and October weather makes threshing catchy.

Wheat seems to stand dry spells better than oats, while barley and flax are much inferior in this respect. These latter crops have been tried time and again but have not become popular. The leading forage crops are brome, alfalfa and sweet clover. These are readily established in strong stands but their production in hay or pasture is not equal to that of wheat or oats. On the whole there is not sufficient early-summer moisture for the growing of timothy, red clover, or alsike. Winter wheat does better at Beaverlodge than at Edmonton, but not as well as in Southern Alberta. The 17-year average yield of Kharkov 22 is 28.7 bushels per acre. In some years killing is attributed to chinook influence, which bares knolls and causes icing in low spots.

It is common practice to fallow one year in four. Rotations should include the use of a forage crop about three years in eight if fibre is to be maintained. Annual and winter annual weeds are particularly troublesome and for the most part the soil tends to blow and wash readily.

The low soil temperature in the early summer, together with the comparatively low precipitation at that time, is not conducive to the rapid formation of soil nitrates. Sod should be broken early if a satisfactory grain crop is expected on the land the following year and no case has been made for cover crops on summerfallow. Winter wheat will turn yellow in late May unless there are surface rains to promote nitrification. This condition may possibly apply in greater degree further North since on the whole the soil in those areas is not particularly rich and the rainfall is low.

Hopkins and Leahey report the average date of the first seeding of wheat as April 28 at Beaverlodge and Lacombe, April 21 at Lethbridge and May 1 at Fort Vermilion. Corresponding harvesting dates are August 25, 26, 8 and 21. In this regard attention is drawn to the report of Albright and Stoker which indicates local incidence in the frost factor.

And, finally, a word about the climate in general. In its natural state there is a fairly complete cover of poplar, willow and spruce, along with other associated species and intermixed with this is a tall growth of grasses and legumes. As breaking takes place the settlers find plenty of moisture for their crops, a generous supply of nitrogen, and a very definite frost hazard because of limited air drainage. As areas open up these factors become moderated and to-day combine harvesting is being considered seriously in areas where crops used to be cut in early September, whether or not they were mature. This earlier harvesting indicates a drier soil climate and emphasizes the need for moisture conservation.

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ASCORBIC ACID CONTENT OF TOMATO VARIETIES AND ITS RETENTION IN PROCESSED PRODUCTS[1]

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Tomatoes are one of the commonly available but variable sources of ascorbic acid. Canned tomatoes and tomato juice are the most important natural sources of ascorbic acid being manufactured in volume in Canada at a reasonable cost to consumers. If properly grown and prepared, these products should be not only attractive and palatable but also a good source of ascorbic acid. Reports published in April, 1944, and in December, 1944, by the Combined Food Board on food consumption levels in the United States, Canada and the United Kingdom showed that in Canada the only vitamin supply seriously deficient was ascorbic acid.

The outstanding value of the tomato in nutrition is due in great measure to its ascorbic acid (vitamin C) content. Published analyses indicate the extreme range that may be found in ascorbic acid content of tomatoes from various sources and at different times of the year. This range is from 5 to 50 milligrams per 100 grams of fresh material. However, the normal range of commercially grown summer varieties is probably 15 to 30 milligrams.

REVIEW OF LITERATURE

There are several published accounts on the ascorbic acid content of varieties and strains of tomatoes, particularly as they occur in the United States. Also a number of investigators have reported on several factors which may be responsible for fluctuations in ascorbic acid content. Excellent reviews on the subject are given by Hamner and Maynard (9), and Maynard and Beeson (17), and corroborated by more recent works. It is apparent that the principal factors affecting ascorbic acid value of tomatoes are variety (genetic factors) and climate, especially light. The latter appears to be of greatest influence the last two weeks of ripening time. Excessive heat may possibly have an adverse effect on the ascorbic acid content according to Reid (20).

A number of papers on the effect of processing on the vitamin C content of tomato juice appeared from 1930 to 1935, employing the bioassay method. These reports, notably Kohman, Eddy and Gurin (13) showed experimentally that if tomato juice were aerated during extraction much of the vitamin C was lost. However, if the tomatoes were crushed and boiled before extraction, or if the juice were immediately subjected to a vacuum, losses were small. Daggs and Eaton (7) examined the manufacture of one brand of commercially canned tomato juice reporting that tomato juice may be canned with little or no loss. By the methods employed at that time, it was difficult to detect small losses even if present.

[1] Contribution No. 657 from the Division of Horticulture, Experimental Farms Service, Dominion Department of Agriculture, Ottawa. Read to Horticultural Group of the Canadian Society of Technical Agriculturists at the Twenty-fifth Annual Convention at Saskatoon, Saskatchewan, June 25 to 28, 1945.

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Recent papers by Tressler and Curran (22), Maclinn and Fellers (16), Fellers and Buck (8), and Hauck (10), employing chemical methods for estimating ascorbic acid, have dealt with certain factors affecting retention of ascorbic acid in preparation and storage of home-processed and experimentally packed tomato juice. Lueck and Pilcher (15) presented information on various factors affecting retention of vitamins and flavour in canned fruit juices. A search of the literature has failed to reveal any comprehensive studies on the effect of processing methods under factory conditions on the retention of ascorbic acid in commercially canned tomato juice or tomatoes.*

A survey in 1942 by the Council on Foods of the American Medical Association (1) of a number of brands of tomato juice canned in the United States, showed a range of from 10 to 28 mg. per 100 grams of juice. The Eastern District (Philadelphia to Buffalo) was low with 10.4 to 13.3 mg., the Central District (Cincinnati to New Orleans) showed 14.9 to 20.7 mg. and the Western District (San Francisco-Denver-Seattle) gave values of 20.7 to 28.0 mg. In 1943 the East and Central Districts showed approximately the same ascorbic acid values and the West was again markedly higher. Another report by the Council on Foods (2) stated that the loss in canning is appreciable in tomato juice and intimated that improvement in the processing of this juice could be anticipated.

MATERIALS AND METHODS

In 1941 studies were commenced by this laboratory on the influence of processing factors on the retention of ascorbic acid in canned tomato juice. Advantage has also been taken of tomato varietal studies to determine the influence of variety on the ascorbic acid content of the canned product. In view of the definite need for maximum retention of vitamin C in commercial canned tomato juice, studies of the various steps in processing

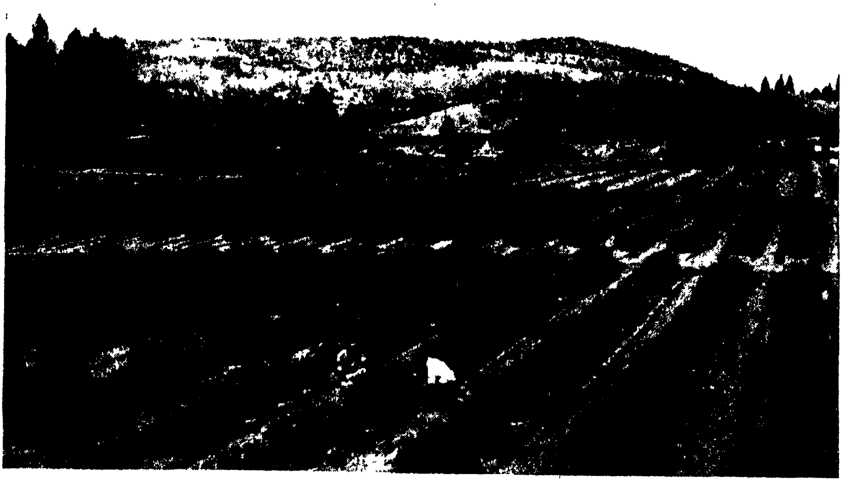

FIGURE 1. Tomato variety test plots at the Dominion Experimental Station, Summerland, B.C.

* See footnote on page 94.

were made under actual operating conditions at several factories in 1943 and 1944. Furthermore, an extensive survey of the ascorbic acid content of canned tomato juice and tomatoes from the three commercial producing areas in Canada, namely, Quebec, Ontario and British Columbia, was made in 1944. This paper presents results of these studies to date.

The tomatoes employed in the study of varietal differences were grown side by side on experimental plots at the Summerland Experimental Station under good cultural and fertilizer conditions on light loam soil. In a number of cases, varieties were grown in the same area over a period of 3 to 4 years. They were harvested at correct canning maturity, prepared and canned in 28-ounce cans in the normal manner, care being taken to exhaust to 160° F. at the centre of the packed can prior to sealing. Two to 3 cans were used for analysis in each case unless otherwise noted. Employing the canned product for determination of the ascorbic acid content of the variety has several advantages, notably from the point of view of convenience and reduction of sampling error. The loss of ascorbic acid on canning under good conditions is insignificant and is comparable for all varieties being tested. Replicate cans were also examined to determine the canning characteristics of each variety. Results of these tests will be reported later.

In testing the influence of processing methods on the ascorbic acid content of tomato juice, 7 or more pounds of tomatoes, usually Earliana 8040, were used to prepare each lot of juice. The basic method of preparation was that described by Atkinson and Strachan (3) for home canned tomato juice. A stainless steel steam jacketed kettle was used for heating the tomatoes and juice to desired temperatures.

In 1944, in co-operation with the Canning Division of the Marketing Service, Dominion Department of Agriculture, 318 samples of tomato juice and 88 samples of canned tomatoes were obtained from the three commercial producing areas in Canada (Quebec, Ontario and British Columbia). These samples were analysed for ascorbic acid and proximate chemical composition and were examined for flavour, colour and other characteristics. Notes were also made of net weight of contents, head space, and vacuum. Only ascorbic acid determinations are being reported in this paper.

Ascorbic acid (reduced) was determined by the sodium 2,6-dichlorophenol indophenol dye visual titration method of Bessey and King (4), employing a 5- to 7-second end point. Daylite fluorescent light and white base were used to increase the accuracy of the end point determination. The dye was standardized according to the method of Buck and Ritchie (5). Occasionally standardization was carried out against pure crystalline ascorbic acid, good agreement being obtained by both methods. The extractions were made with 2% metaphosphoric acid or 0.4% oxalic acid (Ponting, 18).

For juice, 50 ml. were pipetted into a 250-ml. volumetric flask containing extractant, made up to volume with acid extractant, shaken thoroughly and filtered. Five to 15 ml. aliquots were then titrated rapidly with the dye and results reported as mg. per 100 ml. of juice. Where necessary, for certain comparative purposes, the determinations were recalculated to weight basis from the specific gravity of the juice. In nearly all tests, samples were taken in duplicate or triplicate.

For canned tomatoes, determinations were carried out as for juice on 50-gram portions after mixing of the whole contents of the can in a Waring blendor for 30 seconds. This operation permitted more accurate sampling. Tests showed no ascorbic acid was lost by this procedure. In fact, blending 3 to 5 minutes resulted in no decrease of ascorbic acid. Unless otherwise noted 2 or 3 canned samples were examined from each lot or test.

Fresh fruit was prepared for analysis by cutting quarters from 4 fruits to make 100 grams and extracted with 400 ml. of oxalic or metaphosphoric acid extractant in a Waring blendor for 2 minutes and filtered through No. 4 or No. 12 Whatman filter paper. Five to 15 ml. aliquots of the filtrate were titrated with the dye. This method is essentially that described by Loeffler and Ponting (14). The procedure was repeated three or more times for any sample of fruit so that at least 12 representative fruits and usually more were used for each sample, the mean of the individual determinations being recorded.

Tests for interference of metallic ions in the canned product to the dye titration showed that there was none.

RESULTS

The Effect of Variety and Season

In Tables 1 and 2 are presented the ascorbic acid values for 31 different varieties and strains of tomatoes grown under the same conditions at the Summerland Experimental Station. It will be noted from these tables that there was marked variation in ascorbic acid content of varieties. Also while there was considerable variation in ascorbic acid values in the same variety from year to year and even from one picking to another, the varieties tended to maintain their relative position of one to another especially where average difference was marked. These results are in general agreement with the current literature on this question. The Signet variety developed at the Summerland Station is outstanding in its consistently high ascorbic acid content having a 3-year average of 29.8 mg. of ascorbic acid. Its only serious fault is that it lacks size for a good commercial canning tomato. Clarks Early and Sugawara have proved to have consistently good ascorbic acid values but are not outstanding. Fortunately, Clarks Early and Sugawara have good cultural and canning characteristics which make them satisfactory canning varieties under actual commercial conditions in the Okanagan Valley and adjacent areas. Harkness and Bestal (Sd.) have shown consistently fairly good ascorbic acid values but are not satisfactory for other reasons. Master Marglobe, Marglobe × Bonny Best, Stokesdale, Valiant, Livingstone Globe × Gnome and Essary, while having on limited trial apparently good ascorbic acid content, are unsatisfactory in other respects, either not suited to this growing area or else unsatisfactory for canning. California Dawn, a good sized tomato and a satisfactory canner, had on 2 years tests a fairly good ascorbic acid content.

In general, the ascorbic acid contents of the varieties recorded in Tables 1 and 2 compare favourably with the higher results for the same varieties reported in the literature. These high values are probably due in part to favourable climate with respect to temperature and light as

indicated in studies by Reid (19, 20, 21), Wokes and Organ (23) and Kaski, Webster and Kirch (11). It is interesting to note from Table 1 that under conditions prevailing, there was no consistent difference in the ascorbic acid content of tomatoes harvested early and late in the season.

TABLE 1.—ASCORBIC ACID CONTENT OF VARIETIES AND STRAINS OF TOMATOES HARVESTED AT SEVERAL DATES OVER A PERIOD OF THREE TO FOUR YEARS

Variety or strain	Ascorbic acid content in milligrams per 100 grams							Average for 3 or 4 years
	Dates tomatoes harvested and canned							
	1941	1942	1943			1944		
	Sept. 4	Sept. 22	Sept. 10	Sept. 29	Oct. 19	Sept. 6	Sept. 27	
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.
Signet	33.1	—	23.7	29.1	34.9*	21.4	33.7	29.8
Clarks Early	-	31.7	20.9	24.1	23.2*	-	18.9	23.8
Harkness Early	21.7	19.7	21.2	25.1	—	—	—	23.4
Sugawara	24.5	26.3	22.8	25.7	22.0*	20.4	19.0*	23.0
Bestal (Sd.)	23.3	24.7	20.8	21.2	—	—	—	22.5
Dick Locke (Round)	—	22.1	17.1	23.0	23.4	20.5	20.0†	21.1
Signet × Clarks Early (Sd.)	16.4	24.6	20.1	21.5	—	—	—	20.7
Sentinel (Sd.)	—	21.1	16.0	21.7	16.6*	21.4	22.8	20.4
Bounty	16.6	20.7	—	—	—	15.8*	20.8	18.5

* One sample only.
† Another sample from quite different soil (Trout Creek) contained 22.8 mg. ascorbic acid.

TABLE 2.—ASCORBIC ACID CONTENT OF TWENTY-TWO VARIETIES AND STRAINS OF TOMATOES

Variety or strain	Ascorbic acid content in milligrams per 100 grams of canned product			
	1941	1942	1943	1944
	mg.	mg.	mg.	mg.
Master Marglobe (Stokes)	30.5	—	-	—
Marglobe × Bonny Best	30.2	—	—	—
Signet × Sugawara	—	—	—	30.0
Stokesdale (Stokes)	29.3	—	—	—
Valiant (Stokes)	28.3	—	—	—
Sugawara × Signet	—	—	28.1	27.5*
Asgrow Scarlet Dawn	—	—	—	23.8*
Globonnie	26.3	—	—	—
Livingstone Globe × Gnome × L. G. × Abel	26.2		—	—
Essary (Univ. of Tenn.)	25.5	—	—	—
Hybrid 46 (Mich.)	24.4	—	—	—
California Dawn	—	23.6	22.6†	—
8040 (Earliana Sport)	—	25.1	21.2*	—
Signet × John Baer	—	—	—	21.8*
Rutgers (Vineland)	21.5	—	—	—
Rutgers (Stokes)	21.5	—	—	—
Signet × California Dawn	—	—	—	21.7*
Abel	19.9	—	—	—
Bulman's Special (Flat)	—	18.8	20.9†	—
N.D.A.C.	17.9	—	—	—
Bison	17.3	—	—	—
Bulman's Flat (Sd. 993)	—	—	23.0*	15.2

* Average of two pickings.
† Average of three pickings.

The production of a high vitamin C, good quality, heavy yielding tomato with satisfactory canning and juice characteristics appears to be a very urgent problem for the plant breeder. In this connection it is interesting to note that crosses made at the Summerland Station, using the high vitamin C variety Signet as one parent, have given encouraging results. Data presented in Table 3 indicate the possibilities of developing a variety combining high ascorbic acid content with superior cultural and canning characteristics. These data were obtained by analysing fruit from individual plants selected from among many in breeding plots at the Experimental Station. These plants were originally selected on the basis of plant and fruit characteristics suitable for commercial market or cannery production.

TABLE 3.—ASCORBIC ACID CONTENT OF TOMATOES FROM INDIVIDUAL PLANTS, 1943

Plant No.	Parentage	Ascorbic acid content mg. per 100 gm.
		mg.
1-43	John Baer × Signet	34.2
2-43	John Baer × Signet	23.9
3-43	Signet × Calif. Dawn	31.0
4-43	Signet × Calif. Dawn	20.8
5-43	Signet × Calif. Dawn	34.4
6-43	Sugawara × Signet	35.9
7-43	Sugawara × Signet	41.6
8-43	Signet × Sugawara	32.4
9-43	Signet × Sugawara	34.8

Ascorbic Acid Content of Commercially Canned Juice and Tomatoes

The results of a survey of the ascorbic acid values of tomato juice and canned tomatoes as commercially produced are presented in Table 4. There is considerable variation in the ascorbic acid content of tomato juice with somewhat less variation in values for canned tomatoes. However, the most important points to note in this table are: (1) the significantly higher average ascorbic acid content of 22.3 and 19.8 mg. for tomato juice manufactured in British Columbia compared with 14.4 and 15.0 mg. for Eastern Canada; (2) the relatively high minimum values of 12.6 and 15.6 mg. for British Columbia produced tomato juice and the low minimum values of 8.7 and 4.3 mg. for Eastern packed juice while the maxima of both districts are more nearly comparable; (3) the minimum values for ascorbic acid in canned tomatoes are almost identical for both Eastern Canada and British Columbia. These results suggest that many of the low values for tomato juice are to a large extent due to faulty processing and unsatisfactory equipment. The average ascorbic acid values in canned tomatoes from widely separated districts suggest inherent differences which are probably due largely to climate.

TABLE 4.—ASCORBIC ACID CONTENT OF COMMERCIALLY CANNED TOMATOES AND TOMATO JUICE IN CANADA

Year packed	Area	No. of samples analysed	Ascorbic acid values per 100 ml. of juice		
			Average	Maximum	Minimum
			mg.	mg.	mg.
JUICE					
1941	British Columbia	18	22.3	33.3	12.6
1942	Eastern Canada	12	14.4	19.5	8.7
1944	Quebec	44	14.2	26.0	6.1
	Ontario	220	15.1	25.0	4.3
	British Columbia	54	19.8	26.9	15.6
	Eastern Canada	264	15.0	26.0	4.3
TOMATOES			per 100 grams of tomatoes		
1940–41	British Columbia	39	21.6	32.4	14.4
1944	Quebec	5	15.9	18.9	14.1
	Ontario	30	17.2	20.3	15.1
	British Columbia	53	22.5	27.7	16.3
	Eastern Canada	35	17.0	20.3	14.1

Comparison of Ascorbic Acid Content of Juice and Tomatoes Canned Commercially

In order to ascertain how the retention of ascorbic acid in tomato juice compared with that of tomatoes, the data in Table 5 were compiled. The factory from which the samples were secured was well equipped and considered to be packing both products satisfactorily. Canned samples of juice and tomatoes were taken on the same day and also at the same hour when possible. The canned tomato samples obviously represent smaller numbers of fruit than do the juice samples but it is believed there are sufficient samples to make the results significant. Under good processing conditions it would appear that on the average the tomato juice contains about 14% less ascorbic acid than do comparable canned tomatoes. A limited survey of samples from a number of other factories indicates that losses much greater than this occur. Indications are that tomatoes lose very little ascorbic acid in canning. Unpublished data of the Chemistry Division, Science Service, Ottawa (6), showed no significant loss of ascorbic acid in commercial canning of tomatoes.

Studies on Retention of Ascorbic Acid in Tomato Juice Under Factory Conditions

In 1943 it was decided to study ascorbic acid retention under commercial conditions by following the produce as received at the factory through the various processing steps in the plant. This survey was carried out in one plant that year with certain recommendations being made as to improvements in the manufacturing line. The study was repeated in 1944 at the same factory as well as at two additional factories. The results

TABLE 5.—ASCORBIC ACID CONTENT OF CANNED TOMATOES AND TOMATO JUICE PACKED ON SAME DAY AT FACTORY C

(1944 season)

Sample number	Date packed	Ascorbic acid content per 100 grams	
		Juice	Tomatoes
		mg.	mg.
1	Sept. 14	16.7	18.5
2	Sept. 15	21.3	24.3
3	Sept. 19	20.3	22.9
4	Sept. 21	15.2	27.7
5	Sept. 22	21.5	18.9
6	Sept. 23	17.2	21.1
7	Sept. 25	22.5	23.2
8	Sept. 26	22.5	17.8
9	Sept. 27	18.6	21.7
10	Sept. 28	20.2	24.3
11	Sept. 30	19.1	21.1
12	Sept. 30	19.3	—
13	Oct. 2	21.4	23.2
14	Oct. 3	23.5	27.1
15	Oct. 5	23.2	23.4
16	Oct. 6	17.2	23.2
17	Oct. 7	21.2	22.2
18	Oct. 11	20.1	22.2
19	Oct. 13	18.4	20.9
20	Oct. 16	18.1	19.8
21	Oct. 16	15.7	—
22	Oct. 17	26.1	31.6
23	Oct. 18	17.0	24.4
Average		19.8	22.8
Maximum		26.1	27.7
Minimum		15.2	17.8

of the study at Factory C in 1944 are given in Table 6. This factory has what is considered to be a very good tomato juice manufacturing line. Losses were in general smaller and less variable at this plant than in the other two plants investigated. The ascorbic acid figures recorded in Table 6 for raw fruit are very approximate due to the fact that only 12 to 16 fruits were analysed whereas the other figures represent a volume of 50 to 100 gallons of juice or equivalent to around 700 to 1400 pounds of tomatoes. It is unlikely that there was a significant loss at this plant in the hot break due to the few seconds only required following milling to reach the inactivating temperature of 190° F. Hence this figure probably should be taken as representing more nearly the true average ascorbic acid value of the raw product being employed during the tests. On this basis the total loss in processing under good conditions was 2 to 3 mg. or 11.7 to 13.5%. Loss at Factory A was only very slightly greater than at C, but Factory B showed a loss of 18.1 to 26.9%. This was probably due to low temperature extraction allowing enzyme action together with aeration of the product. Losses greater than those found could be expected under such conditions. None of the factories studied permitted contact of the product with copper equipment.

TABLE 6.—RETENTION OF ASCORBIC ACID AT PROGRESSIVE STEPS IN COMMERCIAL PROCESSING OF TOMATO JUICE

Test No.	Steps in processing	Ascorbic acid per 100 gm.
		mg.
	FACTORY C (1944)	
A 1	Raw tomatoes	25.0
2	Emerging from hot break at 200° F.	22.2
3	In finisher receiving tank at 188-190° F.	20.7
4	Holding-salting tank (100 gal.) at 183° F.	19.4
5	After filler prior to sealing can at 182° F.	19.3
6	After canned juice stored three weeks	19.2
B 1	Raw tomatoes	20.8
2	Emerging from hot break at 200° F.	19.6
3	In finisher receiving tank at 188-190° F.	19.2
4	Holding-salting tank (100 gal.) at 183° F.	17.2
5	After filler prior to sealing can at 182° F.	16.3*
6	After canned juice stored three weeks	17.3

* Froth at time of sampling, indicating air in product, likely accounts for this low figure. More frothing seemed to occur with the less mature fruit.

Effect of the Method of Extraction on the Ascorbic Acid Content

Laboratory experiments were carried out to determine the effect of different temperatures employed in preheating the tomatoes prior to extraction and also the actual method of extraction on the ascorbic acid content of the resultant canned juice. The results obtained are reported in Table 7. All tests were made from the same lot of raw tomatoes; 7 to 10 pounds of tomatoes were used for each test. In test No. A, B, J, and K, the tomatoes were placed in a small stainless steel jacketed kettle, pulped while heating in about 5 minutes to 210° F. (boiling at this altitude) using 20-25 lb. steam pressure, boiled specified time, then extracted by various methods. To pass the cooked tomato pulp through the suspended screen by hand required about 3 minutes. Tests C and D were pulped and heated as for A but to lower temperatures. In test E, whole tomatoes were placed in boiling water, and in test F, whole tomatoes were exposed to flowing steam. In tests G, H, and I, whole fruit was extracted without any heating. In all cases, the juice obtained by the various methods of extraction was heated quickly in the kettle to 190° F. and the cans filled full at that temperature, sealed, processed in boiling water 10 minutes and then water cooled.

The very important point brought out in Table 7 is the necessity of rapid heating of the milled pulp to sufficiently high temperature (at least 190° F.) to inactivate quickly the relatively strong oxidase enzymes present in the tomatoes. If this is done, loss of ascorbic acid is relatively small but if not, the loss may be serious as indicated in Table 7 where as much as 36% loss occurred. The actual method of extraction appeared to be of little consequence provided the extraction was on pulp heated to 190° to 210° F. This temperature has the additional advantage that it also inactivates pectin-destroying enzymes resulting in improved consistency of juice as pointed out by Kertesz and Loconti (12).

TABLE 7.—EFFECT OF THE METHOD OF EXTRACTION ON THE ASCORBIC ACID CONTENT OF EXPERIMENTALLY PREPARED CANNED JUICE

Test No.	Method of extraction	Ascorbic acid per 100 ml.	Per cent loss compared to Lot K
		mg.	%
A	Pulped and boiled 3 to 4 min. Extracted hot through screen	30.2	8.5
B	Pulped and boiled ½ to 1 min. Extracted hot through screen	29.6	10.3
C	Pulped and heated to 173° F. Extracted hot through screen	22.4	32.1
D	Pulped and heated to 110° F. Extracted immediately	22.9	30.6
E	Scalded whole 3 min. in boiling water, pulped and extracted immediately through screen	24.5	25.8
F	Scalded whole 2 min. in flowing steam, pulped and extracted immediately through screen	22.9	30.6
G	Pulped and cold extracted through screen	22.5	31.8
H	Pulped and cold extracted through centrifugal juicer	21.8	33.9
I	Pulped and cold extracted through screw expeller press	21.0	36.4
J	Pulped and boiled ½ to 1 min. Extracted hot through small centrifugal juicer	25.2	23.6
K	Pulped and boiled ½ to 1 min. Extracted hot through small screw expeller press	33.0	0.0

Effect of Sterilizing Temperature and Period

To study the effect of sterilizing temperature and time on the ultimate ascorbic acid content of canned tomato juice, several lots of juice were prepared according to Atkinson and Strachan (3) home process procedure. The results of this experiment are recorded in Table 8. The cans in each lot were filled full at 190° F., sealed, sterilized as recorded in the table, and water cooled. Analyses were made after several months storage at 50° F. One-half the cans from each lot of prepared juice were held hot on their sides in the air for 5 minutes or processed in boiling water for 10 minutes for controls. The different lots were not always necessarily prepared from the same fruit. The results show that the sterilizing temperature had very little effect on the final ascorbic acid content of canned tomato juice. This is in agreement with limited data obtained in 1943 under commercial conditions. It was observed that excessive processing temperatures and long processing time had a deleterious effect upon colour and flavour.

SUMMARY

Analyses for ascorbic acid content have been made of 31 varieties and strains of tomatoes grown under identical conditions at the Summerland Experimental Station. A number of the varieties were examined over a period of 3 to 4 years. Clarks Early and Sugawara were found to have consistently good ascorbic acid values and are satisfactory canning tomatoes in this area. The Signet variety proved to be consistently high in ascorbic acid, having a mean value of 29.8 mg. per 100 grams over a 3-year period. Its other characteristics are also good with the exception that it tends to be small. The fruits from individual plants, resulting from crossing Signet with larger fruited varieties, were analysed for ascorbic acid. The results indicate the practicability of developing varieties combining high ascorbic acid content with superior cultural and canning characteristics.

TABLE 8.—EFFECT OF STERILIZING TEMPERATURE AND PERIOD ON ASCORBIC ACID CONTENT OF EXPERIMENTALLY CANNED TOMATO JUICE

Lot No.	Processing data: Sterilizing process	Processing data: Period	Ascorbic acid per 100 ml.
		min.	mg.
1 (a)	210° F. (Boiling water)	10	26.2
(b)	(Held on side in air)	5	26.5
2 (a)	240° F. (Retort)	10	26.6
(b)	210° F. (Boiling water)	10	26.3
3 (a)	240° F. (Retort)	20	27.9
(b)	210° F. (Boiling water)	10	29.3
4 (a)	250° F. (Retort)	5	24.9
(b)	210° F. (Boiling water)	10	25.9
5 (a)	250° F. (Retort)	15	26.8
(b)	210° F. (Boiling water)	10	28.0

A comprehensive survey was made of commercially canned juice and tomatoes in Canada. Marked differences were found in average ascorbic acid content of tomato juice produced in British Columbia and Eastern Canada. In 1941 and 1944 the British Columbia mean values were 22.3 and 19.8 mg., respectively, while the 1942 and 1944 values for Eastern Canada were 14.4 and 15.0 mg. Very low values were found in tomato juice packed in Eastern Canada, yet these low values were not found in the canned tomato samples.

An extensive study was made at three factories of the retention of ascorbic acid in tomato juice under factory conditions. Analyses were made at several steps in the process of manufacture. This study revealed that under good processing conditions the total loss in processing from the raw fruit to the final canned product should not exceed 2 to 3 mg. Loss at many factories apparently greatly exceeds this figure.

Laboratory experiments were conducted on the effect of the method of extraction and the effect of sterilizing temperatures and time on the retention of ascorbic acid in canned tomato juice. The great importance of rapidly heating the milled tomatoes to 190° F.–210° F. prior to extraction was demonstrated. The sterilizing temperature and length of cook had insignificant effect on the ultimate ascorbic acid content of the canned juice. Excessive sterilizing did, however, adversely affect the colour and flavour of the juice.

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PRECANNING TREATMENT ON PROCESSED PLUMS AS IT AFFECTS QUALITY AND VITAMIN C CONTENT[1]

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Preprocessing by scalding in water containing bicarbonate of soda has been generally recommended to remove the acridness present in the skin of most native plums. This practice has been condemned by nutritionists and home economists. The reason for criticism was the belief that the Vitamin C content of the processed fruit was reduced.

During experimental work on fruit varietal quality, at this Station, a study of the effect of preprocessing with bicarbonate of soda, sodium chloride, lye and boiling water on the Vitamin C content of plums was undertaken. Additional treatments were made in an endeavour to find a process that would not reduce the nutritive value and yet would give an attractive, palatable product. Fourteen varieties were used in the test.

Pett and Cantor (1) state that although Vitamin C is the least stable of the vitamins it is quite stable when canned in some foods because of the presence of combined forms. They showed that the Vitamin C content of prunes, dried or canned, is very low. Investigations by Tuba *et al.* (4) on the loss of ascorbic acid in processed native fruits over a period of from 5 to 7 months indicated variations of 0% to 75%. Tuba *et al.* (2), reported in their ascorbic acid determinations of rose hips a technique for preparing materials, using metaphosphoric acid as a fixative and 2,6-dichlorophenol-indophenal for titration. The Vitamin C content of *Prunus melanocarpa* and *Prunus pennsylvanica* as reported by Tuba *et al.* (3) varied from 5 mg. % to 30 mg. %. Hunter and Tuba (unpublished data) found the ascorbic acid value of the Assiniboine plum, a variety comparable with those reported on here, to be 2 mg. %, which is very low when considered from a nutritional standpoint.

EXPERIMENTAL

Varieties of mature plums were washed, pricked, and covered with a thin syrup (1 cup sugar, 2 cups boiling water) and processed in a boiling water bath in number one enamel lined cans for 10 minutes. Processing time was taken from the time the water boiled after the cans were immersed.

Duplicate cans of standard and of each preprocessing treatment were prepared. These treatments were: (a) the fruit was washed, pricked, covered with boiled syrup and sealed; (b) the fruit was washed, pricked and allowed to stand for 5 minutes in boiling water, covered with syrup, and sealed; (c) the fruit was washed, pricked, and allowed to stand for 5 minutes in a hot bicarbonate of soda solution (1.34 gm. (½ teaspoon) soda in one pint of boiling water) and was then rinsed, covered with boiled syrup and sealed; (d) the fruit was washed, pricked, and allowed to stand for 3 minutes in a hot lye solution (11 mg. of lye (commercial NaOH) in

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in one pint of boiling water) which was removed by rinsing, and the fruit was then covered with boiled syrup and sealed; (e) the fruit was washed, pricked, and allowed to stand for 3 minutes in hot saline solution (5.56 gm. (1 teaspoon) of sodium chloride in one pint of boiling water), rinsed, and then covered with boiled syrup and sealed.

Fruit canning quality results were based on score. The score guide evaluated the fruit as to form, colour, skin texture, flesh texture, skin flavour, flesh flavour, juice flavour, and sweetness.

Fruit Quality Score Guide

Form 1-10	10 indicates perfect.
Colour 1-10	10 indicates bright, clean, attractive.
Skin texture 1-10	1 is tough; 10 is tender and thin; above 5 is tender enough to be palatable.
Flexh texture 1-10	1 is soft, mushy, soapy or unpleasantly coarse and stringy; 10 is firm, smooth pleasing.
Skin flavour 1-20	1 is bitter and sour; 20, no bitterness and pleasant.
Flesh flavour 1-20	1 is sour, bitter; 20 aromatic, pleasant, tasty.
Juice flavour 1-10	1 is soft, mushy, soapy or unpleasantly coarse and stringy; 10 is firm, smooth, pleasing.
Sweetness 1-10	1-5 is too sour or too sweet with prefix A for sour, B for sweet; 6-10 desirably sweet as 10 is approached.

The cans were stored at 40° F. for 4 months. Duplicate cans were opened and scored by a testing team of 2 persons. Immediately upon opening the cans, the portions used for Vitamin C determinations were treated with metaphosphoric acid to prevent deterioration of the ascorbic acid.

Determination of Vitamin C Content

The cans were opened and the fruit immediately prepared for ascorbic acid determination; 9 ml. of plum pulp containing skin and 6 ml. of juice were mixed in a Waring Mixer for 2 minutes. Pits were eliminated before mixing the pulp and juice.

Thirty ml. of aqueous extract consisting of 15 ml. of H_2O plus 15 ml. of blended fruit product were used for making the determinations. Ten ml. of 2% metaphosphoric acid ground in 2N hydrochloric acid was added and blended giving 40 ml. of mixture. This was transferred to a graduate centrifuge tube and centrifuged. Precise aliquots of the supernatant fluid were titrated with 2,6-dichlorophenolindophenol.

RESULTS

The varieties tested are listed in Table 1, which shows the standard, standard and boiling water, standard and soda, standard and lye, and standard and salt treatment with the quality scored in percentage under each method and the vitamin C content expressed in mg. %. The methods

are listed in their descending order of average vitamin C content. This does not hold completely throughout the table as there are instances where the soda and lye preprocessing treatment showed a slight improvement in score over the standard method. The two hybrids Opata and Sapa were most markedly affected in this regard. Treatment with bicarbonate of soda and lye accentuated the sweetness in Opata and resulted in a higher total score. Sweetness score for Sapa was constant with the same treatments. The results from a canning standpoint showed that the standard method gave the highest average score for quality and, as was to be expected, retained the greatest vitamin C content. All methods of preprocessing reduced the ascorbic acid content and the quality with a few exceptions was similarly impaired. Varieties with skins typical of *Prunus nigra* were improved in quality or held their own by preprocessing with boiling water.

TABLE 1.—FRUIT VARIETY SCORE AND VITAMIN C CONTENT*

Variety	Standard		Standard and B. water		Standard and soda		Standard and lye		Standard and salt	
	Score	Vitamin content	Score	Vitamin content	Score	Vitamin content	Score	Vitamin content	Score	Vitamin content
Bounty	66	.73	66	.47	68	.33	64	27	60	.40
Brooks 41	68	.60	65	52	64	.40	63	40	—	—
Ember	70	2.60	68	1.80	68	2 20	68	1 27	66	1.73
Etopa	71	1 40	70	93	77	1.73	74	1 60	72	1 47
Emerald	77	2.13	77	.93	77	1 73	74	1 60	72	1.47
La Crescent	88	67	82	.60	85	47	83	.40	80	.47
Louise	75	1 50	74	1 00	74	1 13	65	.75	—	—
McRobert	70	.87	69	.73	69	60	68	67	65	.67
Mina (M 109)	61	1.13	66	.73	61	.40	64	40	—	—
Minn. 255	84	2 00	82	.81	82	.69	82	63	—	—
Opata	84	.73	84	.67	86	.33	86	.40	—	—
Red Wing	77	1.07	70	.52	72	.33	72	.40	69	.60
Sansota	71	.73	64	52	69	.47	64	.33	—	—
Sapa	91	2.06	86	1.40	91	1.27	91	.80	—	—
Average	75.2	1.3	73.0	0.8	74	0.8	72.5	0 6	68.2	0 8

* 100% perfect score. Vitamin content expressed in mg. %.

DISCUSSION

The evidence presented indicates that preprocessing treatments of boiling water, soda, lye and salt impair the quality of the final product. This contradicts the widely held belief that such treatments are beneficial.

All treatments used reduce the vitamin C content to a greater extent than does the standard method. The reduction of the ascorbic acid content is more marked with bicarbonate of soda and lye than are pretreatments with boiling water or salt.

Preprocessing treatments are not recommended, but if one is to be used a mild sodium bicarbonate solution is preferred because of the tendency to give a better final product. The vitamin C content of this final product might be slightly lower than when a boiling water pretreatment is used.

SUMMARY

Preprocessing of native plums with boiling water, soda, lye and salt reduces ascorbic acid content. The treatments do not improve the palatability of the processed product and recommendations of this effect are not advisable.

ACKNOWLEDGMENTS

The authors wish to thank Dr. G. Hunter, Dr. J. Tuba and Miss R. Steele, Department of Biochemistry, University of Alberta, for making available the facilities of their laboratory and for assistance in determinations of vitamin C and the staff of the Provincial Horticultural Station for collecting the fruit varieties.

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THE EFFECT OF EARLY SPRING FLOODING ON CERTAIN FORAGE CROPS[1]

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Since the early settlement of Western Canada many spring flooding projects have been developed, the majority of which are devoted principally to the production of perennial forage crops. This type of forage crop production is vitally important to the livestock industry on the short-grass plains in order to insure feed supplies during dry years. Some of these projects are so constructed that spring run-off water may be held on the land for any desired length of time and then allowed to drain. In other instances drainage is not possible and the spring run-off water remains until lost through seepage and evaporation. This is particularly the case in regard to sloughs of which more and more are being seeded down to perennial crops due to the general difficulties of annual crop production.

It is evident that, in order to survive, any forage crop seeded under such conditions would have to be able to tolerate the longest period of spring flooding which would occur. Because of the demand for information on suitable crops to grow on spring flooding projects and to use for seeding down sloughs, experiments were started in 1939[4] to obtain information on the approximate upper limit of tolerance to early spring flooding of several commonly grown forage crops. In so far as the authors are aware, no experimental data have been published on this subject and consequently no literature is cited.

METHOD

The experiments were started at the Val Marie Irrigation Project in 1939 and continued until 1942. Similar experiments were conducted at the Eastend Irrigation Project in 1940, 1941 and 1942. At Val Marie a saline very heavy clay soil was used and at Eastend a clay loam which was slightly saline. Both irrigation projects are located in south-western Saskatchewan.

The crops tested were seeded between two border ditches in parallel strips from 8 to 10 feet wide depending on the type of drill used. During the first year the stands were irrigated as required and in the fall of the first year dikes were constructed at right angles to the strips of crops.

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[4] The experiments herein reported on were carried out under the direction of Mr. L. B. Thomson, Superintendent, and Dr. S. E. Clarke, Division of Forage Crops, Dominion Experimental Station, Swift Current. The assistance of Mr. S. F. Shields, formerly Manager of the Eastend Irrigation Project, in carrying out the experiments at that Station is acknowledged with thanks.

This arrangement provided a number of basins, each of which could be filled with irrigation water and drained independently of the adjacent basin. The dikes were placed 40 feet apart and the border ditches were 90 feet apart so that each basin measured 40 by 90 feet and contained a plot 40 feet long and 8 or 10 feet wide of each crop to be tested.

In the spring of the second year after seeding and as soon as irrigation water was available, each basin was flooded to a depth of 12 to 18 inches. The water was subsequently drained from each basin at regular intervals ranging from 3 to 49 days after flooding. Flooding was done before growth started, usually in early April, and reflooding from time to time was necessary in order to maintain the water at the desired depth as losses resulted from seepage and evaporation.

All treatments were carried out in duplicate and data were obtained by taking observational notes on the percentage of permanent injury caused to a particular crop by a given period of flooding. These notes were recorded in early July.

The following crops were included in the experiments:

Biennial white sweet clover	(*Melilotus alba* Desv.)
Grimm alfalfa	(*Medicago media* L.)
Fairway crested wheatgrass	(*Agropyron cristatum* (L) Gaertn.)
Parkland brome grass	(*Bromus inermis* Leyss.)
Grazier slender wheatgrass	(*Agropyron pauciflorum* (Schwein) Hitchc.)
Meadow fescue	(*Festuca elatior* L.)
Commercial timothy	(*Phleum pratense* L.)
Reed canary grass	(*Phalaris arundinacea* L.)

RESULTS AND DISCUSSION

Data from the experiments are presented in Tables 1 to 6.

The results obtained from these experiments indicate that among the various forage crops there are wide differences in ability to withstand early spring flooding and furthermore there appears to be a definite upper limit of tolerance for each particular crop. This upper limit, while variable, is essentially similar from year to year and from station to station. Climatic conditions at Eastend are somewhat different to those at Val Marie. The respective elevations are 2,995 and 2,602 feet above sea level; consequently, the frost-free period is shorter and there are cooler conditions in the spring

TABLE 1.—ESTIMATED PERCENTAGE INJURY TO SWEET CLOVER

Number of days flooded	1939	1940	1941	1942	
	Val Marie	Eastend	Val Marie	Val Marie	Eastend
7	0	0	0	0	0
14	5	0	95	65	50
17	65	95	100	100	100
21	100	100	100	100	100

TABLE 2.—ESTIMATED PERCENTAGE INJURY TO ALFALFA

Number of days flooded	1939	1940		1941		1942	
	Val Marie	Val Marie	Eastend	Val Marie	Eastend	Val Marie	Eastend
10	0	0	0	0	0	0	0
14	5	95	0	95	0	5	0
17	25	100	95	100	50	80	50
21	100	100	100	100	100	100	60
28	100	100	100	100	100	100	100

TABLE 3.—ESTIMATED PERCENTAGE INJURY TO CRESTED WHEATGRASS

Number of days flooded	1939	1940		1941	1942	
	Val Marie	Val Marie	Eastend	Val Marie	Val Marie	Eastend
10	0	0	0	0	0	0
14	0	60	25	55	0	10
17	40	85	50	—	0	50
21	100	100	100	100	5	100
28	—	100	100	100	90	100

TABLE 4.—ESTIMATED PERCENTAGE INJURY TO BROME GRASS

Number of days flooded	1939	1940		1941	1942	
	Val Marie*	Val Marie†	Eastend‡	Val Marie	Val Marie	Eastend§
21	0	0	0	0	0	0
24	—	—	0	10	0	0
28	—	50	0	65	0	0
31	—	—	—	85	0	30
35	—	75	—	100	30	50
49	—	—	—	—	100	—

* 21 days longest period flooded in 1939.
† 35 days longest period flooded in 1940.
‡ 28 days longest period flooded in 1940.
§ 35 days longest period flooded in 1942.

TABLE 5.—ESTIMATED PERCENTAGE INJURY TO SLENDER WHEATGRASS

Number of days flooded	1941	1942	
	Val Marie*	Val Marie	Eastend†
28	0	0	0
31	0	—	10
35	5	40	45
42	—	—	—
49	—	100	—

* 35 days longest period flooded in 1941.
† 35 days longest period flooded in 1942.

TABLE 6.—ESTIMATED PERCENTAGE INJURY TO MEADOW FESCUE

Number of days flooded	1941	1942	
	Val Marie*	Val Marie	Eastend†
24	10	0	0
28	45	0	25
31	80	0	30
35	100	0	45
49	—	0	—

* 35 days longest period flooded in 1941.
† 35 days longest period flooded in 1942.

at Eastend. This may account for the fact that the various crops tested there appeared to withstand slightly longer periods of flooding at this Station. This is also probably due to some extent to the fact that difficulty was usually experienced in obtaining proper flooding at the beginning of the experiments at Eastend. The soil here has good sub-surface drainage and the initial floodings each year seeped away necessitating continuous reflooding until a satisfactory level could be maintained on the plots. Such was not the case at Val Marie as the soil is relatively impervious and here the first flooding was usually satisfactory, reflooding only being necessary to make up for evaporation and slight seepage losses.

It was observed that the nature of the weather in the spring of the year influenced considerably the length of time some crops may be flooded. The average monthly temperatures for April, May and June in 1941 and 1942 at Swift Current, the closest Station for which records are available, are shown in Table 7. These data indicate the differences between the two seasons.

A cool spring appeared to increase the tolerance of crested wheatgrass, brome, meadow fescue, alfalfa and sweet clover, whereas a warm spring had the opposite effect. For example, alfalfa sustained 95% damage at Val Marie in 1941, a warm spring year, from 14 days flooding, and 50% at Eastend, from 17 days flooding. In 1942, a cool spring, alfalfa at Val Marie only suffered 5% damage in 14 days. In that year at Eastend alfalfa was damaged to the same extent in 17 days as it had been in 1941 but was not completely killed out until it had been flooded a total of 28 days whereas in 1941 it was killed out in 21 days. Similar situations in these two years with respect to other crops are apparent.

There is some indication that cool spring weather exerts an opposite effect on slender wheatgrass. While only a small amount of damage resulted from 35 days flooding at Val Marie in 1941, there was 40% injury sustained in 1942 when cool conditions prevailed.

Timothy and reed canary grass were included in the experiments at Val Marie in 1941 and 1942 and at Eastend in 1942. These two grasses were not injured by 35 and 49 days flooding at Val Marie or by 35 days at Eastend. These two crops were the most resistant of those tested and appear to be most suitable for locations where extended periods of flooding occur. Table 8 indicates the range in days that the various crops may be spring flooded without causing excessive permanent injury as determined by the experiments reported on.

FIGURE 1. General view of the experiment at Val Marie in 1942, showing basins filled with water in the early spring.

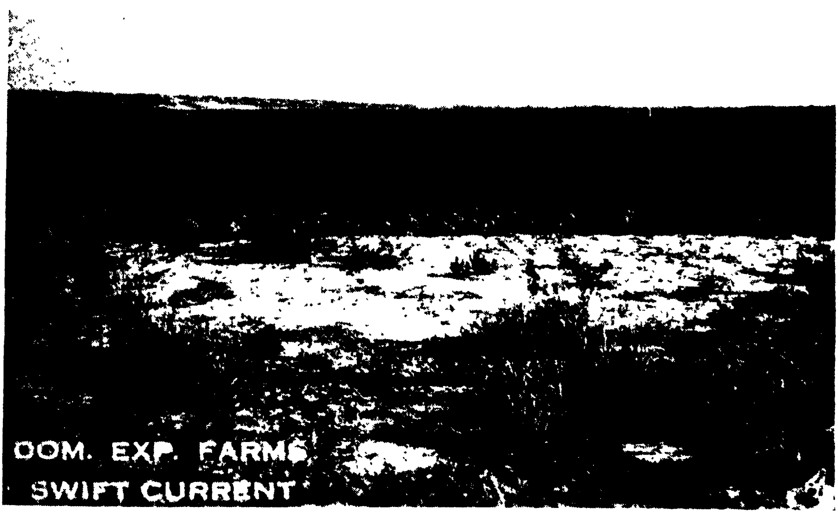

FIGURE 2. Alfalfa spring flooded for 3 days (background) and 21 days (foreground).

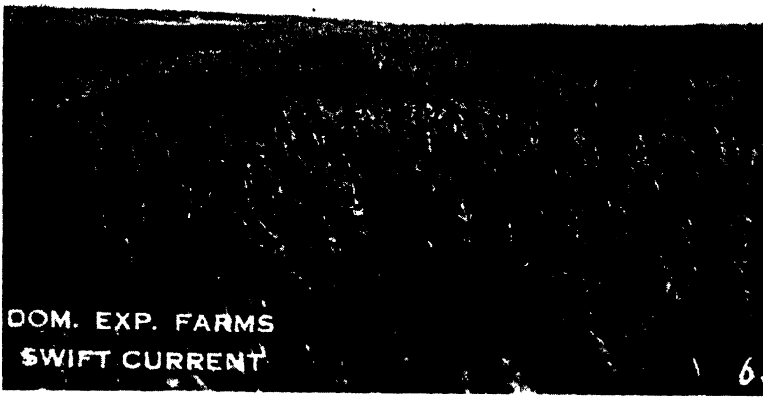

FIGURE 3. Brome grass flooded for 3 days (background) and 21 days (foreground).

FIGURE 4. Sweet clover flooded for 3 days (background) and 21 days (foreground).

TABLE 7.—AVERAGE MONTHLY TEMPERATURES AT SWIFT CURRENT IN 1941 AND 1942

Month	1941	1942
April	43.0	43.5
May	53.6	48.4
June	62.5	56.6

TABLE 8.—RANGE IN DAYS WHICH CERTAIN FORAGE CROPS MAY BE SPRING FLOODED WITHOUT CAUSING EXCESSIVE PERMANENT INJURY

Crop	Number of days	Crop	Number of days
Sweet clover	9–12	Slender wheatgrass	31–35
Alfalfa	10–14	Meadow fescue	24–35
Crested wheatgrass	10–17	Timothy	49*
Brome	24–28	Reed canary grass	49*

* Forty-nine days longest period tested. These two crops apparently will stand longer periods, particularly reed canary grass.

Sweet clover, alfalfa and crested wheatgrass may be classed as crops tolerant of shorter spring flooding periods, brome, slender wheatgrass and meadow fescue of relatively long periods, and timothy and reed canary grass of extended periods of flooding. Under practical irrigation conditions, this general relationship holds true during mid-season growing conditions as well and it has been observed that crops such as alfalfa are particularly sensitive to over irrigation or poor drainage of irrigation water whereas brome, slender wheat, meadow fescue, timothy and reed canary grass are not visibly affected.

The experimental results furnish a basis for advising farmers and ranchers as to the forage crop they should grow under their particular conditions, providing information is available on the approximate length of time their land is flooded in the spring. Suitable mixtures may also be worked out from the data obtained.

SUMMARY

As a result of the need for information on forage crops to grown under spring flooding conditions, experiments were conducted at the Val Marie and Eastend Irrigation Projects from 1939 to 1942 to determine the length of time which certain commonly grown forage crops may be covered with water without causing excessive permanent injury. Sweet clover, alfalfa and crested wheatgrass were able to withstand only short periods of flooding while brome, slender wheatgrass and meadow fescue were able to stand fairly long periods. Timothy and reed canary grass stood the most flooding of the crops tested.

PRELIMINARY EXPERIMENTS WITH BENZENE HEXACHLORIDE (666) AS AN INSECTICIDE[1]

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[Received for publication January 16, 1946]

The insecticidal properties of benzene hexachloride, more precisely 1,2,3,4,5,6-hexachlorocyclohexane, $C_6H_6Cl_6$, and now commonly referred to as 666, appear to have been first discovered in France, where a patent for its preparation was issued as early as 1941, according to Bourne (1). It has been sold there for some years under the trade name of "Aphtiria," and was used in large quantities during the war by the French Government. In 1942 workers in England independently discovered its toxicity to insects, and it was quickly developed and used in quantity as an emergency insecticide, particularly against flea beetles. The history of its early development in England, for some time kept under military secrecy, has recently been published by Slade (2), who also gives an outline of its chemistry.

According to Slade, crude 666 is largely a mixture of the four known stereo-isomers of hexachlorocyclohexane, designated alpha, beta, gamma and delta, of which only the gamma isomer has appreciable insecticidal properties. Slade has suggested that the gamma isomer be known as *gammexane.* Crude 666, which is a pale brownish solid with a very pronounced, penetrating odour, contains 10 to 12% gamma isomer. The pure gamma isomer is a colourless crystalline solid, practically odourless, with a melting point of 112.5° C., insoluble in water but dissolving in many organic solvents. Because of difficulty in separating the isomers it is unlikely that the pure gamma isomer will be produced commercially, but so-called refined 666 containing up to 40% gamma isomer has been prepared.

Because of the similarity in solubility and other physical properties, 666 can in general be processed in the same manner as DDT. Like the latter, undiluted 666 is not suitable for most insecticidal uses because the slightly waxy consistency of the crude or refined material makes it very difficult to grind undiluted to the required degree of fineness. It is also difficult to wet. Dusts of 666 can be prepared by grinding with an inert powder such as talc, clay or pyrophyllite, and wettable spray powders in the same manner by adding a dispersing agent. It can also be dissolved in appropriate solvents and used as a solution, or the latter can be emulsified in water.

This paper presents the results of exploratory tests with small samples of 666 which were received at Vineland Station in 1944 and 1945.

MATERIALS AND FORMULATIONS

The materials tested at this laboratory to date have been the following, all except the last two being obtained from England[5]: (a) Pure gamma isomer; a five-gram sample; (b) crude 666, containing 10 to 12% gamma isomer; (c) refined 666, containing 30 to 40% gamma isomer; (d) a finely

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ground mixture of 20 parts crude 666 and 80 parts gypsum; (e) a miscible oil solution containing 17% crude 666; (f) a wettable spray powder containing 50% of a partially refined 666, the gamma content of the latter being approximately 22%. This sample was received from the United States[6] and will be referred to as American 666; (g) a dust containing 5% of American 666 (22% gamma). The gamma content in all cases is that given by the manufacturers. The methods used in determining these values are not known to the writers.

Most of the experiments were conducted with a standard wettable spray powder prepared in the laboratory by grinding for 17 hours in a ball mill the following: 666 (either pure gamma isomer, crude 666 or refined 666) 10%, Orvus (wetting agent containing 32% sodium lauryl sulphate) 3%, and pyrophyllite 87%. A similar formulation containing commercial DDT was used for comparative purposes. *Unless otherwise stated the10-3-87 formula was used and the Orvus concentration in the dilute spray adjusted to ½ lb. per 100 gallons.* Other formulae for dusts and sprays are described in the text.

The method of stating the composition of the spray or dust is as follows: in the tables the amounts in pounds per 100 gallons refer to the actual amount of crude 666, refined 666 or DDT as the case may be, and *not* to the amount of the complete formulation. In addition the approximate gamma isomer content in pounds per 100 gallons of spray is given in some cases. The latter is an average figure derived from the range stated by the manufacturer, viz., 11% for crude 666 and 35% for refined 666.

Test Insects and Methods

Experiments were conducted with 14 species of insects and 2 mites, some of which were chosen not for their economic importance but because they lent themselves readily to laboratory testing. As the work progressed it became evident that 666 had fumigant as well as contact and stomach poisoning action and consequently special techniques had to be devised.

Sprays were applied in all cases with a De Vilbiss paint sprayer, usually with the spray gun mounted on a rigid stand and the spray material mechanically agitated.

Codling Moth (*Carpocapsa pomonella* (L.)) and Oriental Fruit Moth (*Grapholitha molesta* (Busck.))

Toxicity of 666 to Newly Hatched Codling Moth Larvae

Wealthy apples were picked before maturity in 1944 and kept in cold storage until required in the early spring of 1945, when they were washed in 2% hydrochloric acid to remove old spray residue. After the calyx and stem ends were waxed, the fruits were sprayed individually, being revolved in the spray cone of a paint atomizer for 12 seconds in a machine specially constructed for this work. Codling moth eggs were obtained on waxed paper from moths reared from field-collected larvae. As soon as the spray had dried on the fruit, 10 eggs hatching within the next 24 hours

[5] Imperial Chemical Industries Ltd., Liverpool, England.
[6] Niagara Sprayer and Chemical Co., Inc., Middleport, N.Y.

were pinned on each apple and incubated at 77° F. and 75 to 85% relative humidity. Ten apples were used for each individual test. Both stings and entries were recorded three days later but the number of stings was so erratic that they have not been further considered. The entries in an unsprayed check (10 fruits—approximately 100 larvae), run along with the sprayed fruit in each day's test, were employed in calculating the percentage efficiency of the sprays according to Abbott's formula (J. Econ. Ent. 18 : 265-267).

For comparative purposes, both pure gamma 666 and relatively pure DDT (96 to 99% para-para isomer) were used in the form of the 10-3-87 grind with Orvus and pyrophyllite already described. Crude 666 was not employed in this form because the high concentration of the mixture required would contain too great a proportion of wetter. Lignin pitch was therefore used as a dispersing agent in grinds containing 10 parts crude 666, lignin pitch 3 parts, and pyrophyllite 87 parts; or 20 parts crude 666, lignin pitch 3 parts, and pyrophyllite 77 parts by weight. The preparation containing 20% crude 666 in gypsum was also tested. No wetter was employed in any of the tests beyond that already present in the dry formulation.

The results of the tests, shown in Table 1, indicated that pure gamma 666 was distinctly more toxic to codling moth larvae than DDT. The small sample of pure gamma 666 available prevented an extensive series of tests, but the data obtained suggested that its toxicity to codling moth larvae was in the neighbourhood of one and one-half times that of the para-para isomer of DDT.

TABLE 1.—RELATIVE TOXICITY OF 666 AND DDT TO NEWLY HATCHED CODLING MOTH LARVAE

Materials	Lb. per 100 gal.	Approx. gamma isomer content; lb. per 100 gal.	No. of replicates	Percentage efficiency (Abbott)
DDT (10-3-87 DDT-Orvus-pyrophyllite)	0.25	—	3	60.1
DDT (as above)	0.5	—	4	80.0
Pure gamma 666 (10-3-87 gamma isomer-Orvus-pyrophyllite)	0.25	0.25	3	73.6
Pure gamma 666 (as above)	0.5	0.5	3	93.3
Crude 666 (10-3-87, 666-lignin pitch-pyrophyllite)	2.5	0.275	4	58.4
Crude 666 (20-80, 666-gypsum)	5.0	0.55	4	87.9
Crude 666 (20-3-77, 666-lignin pitch-pyrophyllite)	5.0	0.55	4	82.2

N.B.—Additional Orvus was not added to any of the above sprays.

Crude 666 was less effective than its gamma isomer content of 10 to 12% would suggest. This may have resulted from the large amount of inert material, both from the original crude 666 and the pyrophyllite or

gypsum used in processing. The slight difference in favour of the 20% crude 666 in gypsum over the same amount in pyrophyllite may have been due to the lignin pitch in the latter mixture causing greater run-off.

Toxicity of 666 to Adult Codling Moths and Oriental Fruit Moths

Adult codling moths were confined in cloth-topped battery jars with apple twigs sprayed with refined 666 (20% ground in pyrophyllite without wetter) at 1 lb. per 100 gal. Females placed with twigs sprayed the same day died within an average of 3.5 days without producing any eggs, while females placed with twigs sprayed two days previously lived an average of 11.7 days and averaged 55.8 eggs. In the check jars, average longevity was 14.3 days and average egg production 57.5 eggs per female.

Lack of moths prevented further tests with codling moth, so adult oriental fruit moths were used to investigate the manner in which 666 acted. When the moths were placed free in battery jars with a sprayed twig, or when they were confined in a wire screen cage within the battery jar so that they could not come in contact with the spray residue, mortality was complete within 24 hours. Longevity of females was also reduced to 4 days, as compared with 8.8 days in the checks, when the moths were confined in battery jars with a gauze-topped can containing dry refined 666. On the other hand, female moths confined with freshly sprayed twigs in open wire screen cylinders in the insectary lived as long as in the checks (an average of 9.9 days in both) and actually deposited a larger number of eggs. Oviposition was very erratic in all cages, however, and the differences were probably not significant.

It is apparent that the vapours given off by 666 spray residues for a short time are very toxic to the adults of both codling moth and oriental fruit moth within a confined space, but it is doubtful whether sprays of 666 would have any appreciable residual effect on the moths under orchard conditions. The effect of actually hitting the moths with 666 sprays was not investigated.

Diamondback Moth (*Plutella maculipennis* (Curt.))

Larvae were raised in mass rearing cultures and those in the last two instars removed for the tests which were conducted in the greenhouse. Two methods of treatment were employed: (a) Larvae on sheets of paper were sprayed for 10 seconds, and at once transferred to untreated pieces of cabbage leaves about 3 sq. in. in area in straight-sided 16-oz. glass jars covered with factory cotton. A strip of moist dental cotton was placed in the jar. This test was for direct contact toxicity. (b) Pieces of sprayed cabbage foliage about 3 sq. in. in area were placed in the jars after the spray had dried, and unsprayed larvae added. This was considered as a stomach poison test, but there was also residual contact action and possibly some fumigant action. In most cases 15 larvae were used per jar and 3 jars per individual test.

The first test indicated that the direct contact action of crude 666 suspensions was much less than that of DDT suspensions, e.g., crude 666 at 4 lb. per 100 gal. gave a kill of 56%, while approximately the same mortality was obtained from 0.25 lb., or one-tenth the amount of DDT. It was shown in another test that 666 was more effective by contact when applied in emulsion form or as a precipitated suspension, than as a suspension made with a wettable spray powder. The emulsion was prepared by diluting 1-200 with water the following stock:

Crude 666—10 grams.
Triton X-100*—10 cc.
Velsicol AR-60†—approx. 86 cc. (to make 100 cc. of solution).

The precipitated suspension was prepared by dilution of a similar stock in which acetone replaced the Velsicol. A proprietary miscible oil solution containing 17% crude 666 was also tested. Dilutions at a rate of 0.5 lb. crude 666 per 100 gal. gave the following results, using 30 larvae per treatment:

Powder suspension	3.3% mortality.
Velsicol emulsion	33.3% mortality.
Proprietary oil emulsion	26.6% mortality.
Acetone suspension	20.0% mortality.

Both DDT and 666 were more effective as stomach poisons than as contact sprays, but again DDT was relatively more toxic than 666. This is shown in Table 2 which is a summary of the data from several tests. Each figure in the table is an average, derived from two or three tests, representing a total of 90 to 135 larvae. It will be noted that the kills by 0.125 lb. gamma 666, 1 lb. crude 666, and 0.062 lb. DDT are approximately equivalent, and similarly the kills for double these amounts of each, hence in these tests DDT was roughly twice as toxic as pure gamma 666, and 16 times as toxic as crude 666.

TABLE 2.—COMPARISON OF CRUDE 666, GAMMA 666, AND DDT AS STOMACH POISONS AGAINST LAST TWO INSTAR DIAMONDBACK MOTH LARVAE

Lb. per 100 gal.	Material and percentage mortality		
	Gamma 666	Crude 666	DDT
	%	%	%
0.031	—	—	50.0
0.062	—	—	53.3
0.125	61.6	12.2	76.6
0.25	71.1	29.4	80.0
0.5	77.7	53.8	93.3
1.0	100.0	53.6	96.6
2.0	100.0	70.5	—
4.0	—	81.0	—

Greenhouse Leaf Tier (*Phlyctaenia rubigalis* (Guen.))

Two tests against the larvae of this species gave almost the same results as obtained with diamondback moth larvae. One test was conducted in the greenhouse with adults, where untreated moths were placed

* A proprietary emulsifier and wetting agent.
† Largely a mixture of methyl naphthalenes.

in (a) an unsprayed wire screen cage with a sprayed plant, and (b) in a sprayed cage with a sprayed plant. Thirty-five adults were used per cage. DDT and gamma 666 were compared at the rate of 1 lb. per 100 gal. The results summarized in Table 3 show that under the conditions of this experiment, gamma 666 was more toxic than DDT, and that as would be expected spraying the cage as well as the plant increased the effectiveness of the treatments.

TABLE 3.—COMPARISON OF DDT AND GAMMA 666 AGAINST ADULT GREENHOUSE LEAF TIERS

Condition of test	Material	Lb. per 100 gal.	No. eggs laid	Length of life; days	
				Max.	Av.
Plant sprayed	DDT	1	388	8	3.8
Plant sprayed	Gamma 666	1	73	2	1.1
Plant and cage sprayed	DDT	1	5	3	1.4
Plant and cage sprayed	Gamma 666	1	40	2	1.0
Check—untreated	—	—	811*	over 8	—

* When observations were discontinued after 8 days about 40% of the moths were still living in the check, so more than 811 eggs would have been laid.

Strawberry Leaf Roller (*Ancylis comptana fragariae* (Walsh & Riley))

This insect, which is much more resistant than diamondback moth and greenhouse leaf tier to DDT, appears to be also quite resistant to 666, the relative difference in toxicity between DDT and 666 appearing about the same as for diamondback moth larvae.

Potted strawberry plants were sprayed in the greenhouse and after the deposit had dried, 14 to 20 nearly mature larvae, collected from the field, were placed on each plant. The data from several tests, summarized in Table 4, indicated that the kill obtained from 2 lb. DDT approximated that from 2 lb. refined 666, but that at the 1-lb. rate DDT was considerably more effective.

TABLE 4.—EFFECT OF DDT AND 666 ON STRAWBERRY LEAF ROLLER LARVAE ON POTTED STRAWBERRY PLANTS

Material	Lb. per 100 gal.	Approx. gamma isomer content; lb. per 100 gal.	No. larvae	No. survived	Mortality
					%
DDT	1	—	160	32	80.0
DDT	2	—	160	18	88.7
DDT	3	—	60	6	90.0
Crude 666	1	0.11	40	31	22.5
Crude 666	2	0.22	40	24	40.0
Refined 666	1	0.35	60	28	53.3
Refined 666	2	0.7	60	11	81.6
American 666	2	0.44	60	23	61.6
American 666	4	0.88	60	9	85.0
American 666	6	1.32	60	9	85.0
Check	—	—	160	138	13.7

Retention of Toxicity by Spray Deposits of DDT and 666

Strawberry plants were sprayed and infested with larvae as soon as the deposit dried. Results were taken 4 days later, and then one week after being sprayed the plants were reinfested. The results were erratic, but, as shown in Table 5, the loss of toxicity by either material was slight, although somewhat greater in the case of 666.

TABLE 5.—COMPARISON OF TOXICITY OF FRESH AND WEEK-OLD DEPOSITS OF DDT AND 666 AGAINST STRAWBERRY LEAF ROLLER LARVAE. SIXTY LARVAE PER TREATMENT

Material	Lb. per 100 gal.	Approx. gamma isomer content; lb. per 100 gal.	Percentage mortality	
			Fresh deposit	1-week-old deposit
			%	%
DDT	1	—	76.6	86.6
DDT	2	—	88.3	83.3
DDT	3	—	90.0	86.6
American 666	2	0.44	61.0	50.0
American 666	4	0.88	85.0	73.4
American 666	6	1.32	85.0	86.6

Asparagus Beetle (*Crioceris asparagi* (L.)) and Spotted Asparagus Beetle (*Crioceris duodecimpunctata* (L.))

In a number of insectary experiments in which untreated adults were placed in cylindrical wire screen cages with sprayed asparagus foliage it was found that DDT was much more effective than 666 against the common asparagus beetle, but apparently somewhat less effective than 666 against the spotted species. For example, as shown in Table 6, 0.125 lb. DDT killed 61% of the former species while the same amount of crude 666 killed 9%, and 0.66 lb. refined 666 killed only 28%. In the case of the spotted

TABLE 6.—EFFECT OF DDT AND 666 ON ASPARAGUS BEETLES. ONE HUNDRED COMMON AND TWENTY-FIVE SPOTTED ASPARAGUS BEETLES PER TEST

Material	Lb. per 100 gal.	Approx. gamma isomer content; lb. per 100 gal.	Percentage mortality	
			Common	Spotted
			%	%
DDT	0.125	—	61.0	—
DDT	0.25	—	93.0	—
DDT	0.5	—	100.0	28.0
DDT	2.0	—	—	64.0
Crude 666	0.125	0.013	9.0	—
Crude 666	0.5	0.055	24.0	—
Crude 666	1.0	0.11	34.0	—
Crude 666	2.0	0.22	45.0	52.0
Crude 666	4.0	0.44	—	52.0
Refined 666	0.33	0.11	14.0	—
Refined 666	0.66	0.23	28.0	52.0
Refined 666	1.32	0.46	—	72.0
Check	—	—	2.0	0.0

species the kill by 0.33 lb. refined 666 was higher than that by 0.5 lb. DDT. Other data in this table show that crude 666 was relatively more effective than refined 666 on the basis of gamma content, e.g., crude 666 at gamma rates of 0.1 and 0.2 lb. per 100 gal. killed 34.0 and 45.0%, respectively of the common asparagus beetle, while refined 666 at the same gamma rates killed 14.0 and 28.0%, respectively.

Striped Cucumber Beetle (*Diabrotica vittata* (F.))

Adults of this species were shown to be very susceptible to both DDT and 666 when placed in cages with sprayed plants. DDT at the lowest rate tested, 0.125 lb. per 100 gal., killed 100%, while crude 666 at 0.125, 0.25 and 0.5 lb. per 100 gal. killed 71.5, 88.5, and 94.5%, respectively. Refined 666 at 0.5 lb. per 100 gal. gave 100% mortality.

An estimate of the amount of foliage consumed by the beetles showed better protection by DDT than by 666, e.g., the proportion consumed of foliage sprayed with crude 666 at 0.125, 0.25 and 0.5 lb. per 100 gal. being 5, 20 and 30%, respectively; and for DDT at the same rates it was trace, 1 and 3%, respectively.

Rose Chafer (*Macrodactylus subspinosus* (F.))

A number of tests were conducted in the insectary in July but the results were unsatisfactory owing to the age of the beetles which resulted in mortalities of 50 to 60% in the checks during the observation period. However, it is worth noting that crude 666 appeared to be about equally as toxic as DDT, e.g., in a test at rates varying from 0.062 to 0.25 lb. per 100 gal. both crude 666 and DDT killed approximately 85% at the lowest rate and 100% at the highest, while the mortality from lead arsenate at 5 lb. per 100 gal. was only 75%.

Pear Psylla (*Psylla pyricola* Foerst.)

To determine the action of 666 on pear psylla nymphs, infested potted plants or infested shoots from the orchard which bore nymphs of all instars were used. From the time of spraying to examination, a period of from 3 to 5 days, sprayed and check plants were kept unconfined in the insectary.

Adults had to be caged, and since they are able to pass through 16-mesh screening, either 40-oz. wide-mouth glass containers or 32-mesh wire gauze cages were used. In all instances sprayed twigs were allowed to dry before being put in the cages with adults.

Relative Toxicity of DDT and 666 Against Nymphs

An initial test, the results of which are summarized in Table 7, showed that crude 666 was much more effective than DDT, a powder suspension spray of the latter at 1 lb. per 100 gal. killing only 16.7% as compared with 91.2% by 0.25 lb. of crude 666. It is interesting to note that a powder suspension of DDT is less effective as a contact spray than an emulsion (Velsicol) or precipitated suspension spray (acetone) of DDT.

TABLE 7.—COMPARISON OF DDT AND 666 SPRAYS AGAINST PEAR PSYLLA NYMPHS

Materials	Lb. per 100 gal.	No. of tests	Total nymphs	Percentage mortality
DDT (powder suspension)	1	3	1467	16.7
DDT (Velsicol emulsion)*	1	3	1342	51.9
DDT (precip. acetone suspension)†	1	3	1234	43.0
Crude 666	1	4	1974	99.9
Crude 666	0.5	6	1998	88.6‡
Crude 666	0.25	2	728	91.2
Checks ..	—	5	1483	4.5

* and † Prepared by diluting: DDT 20 gm.
Triton X-100 10 cc.
Velsicol AR-60 or
Acetone to make 100 cc.

‡ Living nymphs were largely those newly hatched from eggs present before spraying.

In a series of dosage tests, summarized in Table 8, it was found that crude 666 at a rate as low as 0.25 lb. per 100 gal. gave a kill of over 85%, and refined 666 at 0.2 lb. per 100 gal. gave a similarly high mortality. It appears that crude 666 is relatively more toxic than its gamma isomer content would indicate.

TABLE 8.—DOSAGE TESTS OF 666 ON PEAR PSYLLA NYMPHS

Materials	Lb. per 100 gal.	Approx. gamma isomer content; lb. per 100 gal.	No. tests	Total nymphs	Percentage mortality
Crude 666	2	0.22	2	929	100.0
Crude 666	1	0.11	5	3012	99.5
Crude 666	0.5	0.05	4	1589	96.8
Crude 666	0.25	0.027	3	1577	86.9
Crude 666	0.2	0.022	1	644	51.5
Refined 666	1	0.35	2	681	97.1
Refined 666	0.5	0.175	8	5726	98.2
Refined 666	0.25	0.087	2	514	79.6
Refined 666	0.2	0.07	2	735	86.9
Refined 666	0.1	0.035	2	612	55.1
Checks	—	—	10	5751	4.3

Residual Action of 666 on Pear Psylla Nymphs

Small potted seedlings bearing psylla eggs were sprayed with various strengths of 666 at periods when the eggs were at different stages of development. No cages were used on the plants after the sprays were applied. When the psyllas had reached the first and second instars, examinations were made to determine if the sprays applied before hatching had destroyed the nymphs.

The results given in Table 9 showed that 666 sprays had no apparent lethal action on the eggs but killed large percentages of nymphs hatching from eggs present on sprayed foliage. Sprays applied nearest to the time of hatching were more effective than those applied earlier.

TABLE 9.—RESIDUAL ACTION OF 666 ON PEAR PSYLLA NYMPHS

Materials	Lb. per 100 gal.	Approx. gamma isomer content; lb. per 100 gal.	Age of eggs* when sprayed	Total nymphs	Percentage mortality
			days		
Crude 666	1.0	0.11	1–7	310	85.5
			3–10	291	92.8
			7–10	223	96.8
Crude 666	0.5	0.055	1–7	368	58.7
			3–10	220	83.3
			7–10	251	88.9
Crude 666	0.25	0.027	1–7	296	50.6
			2–10	320	70.6
			7–10	312	42.2
Refined 666	1.0	0.35	7–10	134	95.5

* Total incubation period was 10 to 12 days.

Fumigant Action of 666

Table 10 shows that 666 has a pronounced fumigant action on adult pear psyllas within a confined space. Adults enclosed in cloth-covered glass containers with crude 666, but separated from it by wire gauze, were all killed within a 6-day period, and laid an average of 1.3 eggs per psylla. When a fine mesh wire gauze cage was used instead of the glass jar to allow air circulation, the mortality was greatly reduced and large numbers of eggs were deposited. However, adults confined on sprayed twigs succumbed as rapidly in a gauze cage as in a glass container.

TABLE 10.—FUMIGANT ACTION OF CRUDE 666 ON PEAR PSYLLA ADULTS

Method of use	Total adults	Percentage mortality after:			Total eggs laid	Average no. eggs per adult
		1 day	3 days	6 days		
		%	%	%		
Dry crude 666 (10 gm.) placed in bottom of quart glass jar and separated by fine wire gauze from psyllas and pear twig placed above	23	74.0	82.6	100.0	29	1.3
As above, but wire gauze cage used in place of glass jar	23	0.0	17.4*	17.4*	1009	44.0
Check; as above, with wire gauze cage but without 666	21	0.0	0.0	0.0	1440	68.9
Twig sprayed with 1 lb. crude 666 per 100 gal. in glass jar with psyllas	44	100.0	-	—	0	0
Check; as above but twig not sprayed	40	7.5	12.5	35.0	496	12.4
Twig sprayed with 1 lb. crude 666 per 100 gal. in wire gauze cage with psyllas	25	100.0	—		7	0.3
Check; as above but twig not sprayed	20	0.0	0.0	0.0	216	10.8

* Partly estimated because of poor visibility through fine gauze.

Persistence of Toxicity of 666 Residues

Pear twigs in jars of water were sprayed with crude 666 at 1 lb. per 100 gal., and at daily intervals thereafter placed in cloth-covered glass containers along with pear psylla adults.

The results in Table 11, especially those taken one day after caging, show a general trend of decreasing mortality and higher egg deposition as the interval after spraying was increased. There might have been fewer inconsistencies in the final records if lower rates of 666 had been used. It should be noted that the psyllas were confined in glass containers so that the 666 could act both as a fumigant and as a contact insecticide.

TABLE 11.—PERSISTENCE OF RESIDUAL ACTION OF CRUDE 666 1 LB. PER 100 GAL. ON PEAR FOLIAGE AGAINST ADULT PEAR PSYLLA

Age of spray deposit; days	No. of tests	Total adults	Percentage mortality after:				Final records after 7 days:	
			1 day	3 days	5 days	7 days	Total eggs laid	Aver. no. eggs per adult.
			%	%	%	%		
Fresh	2	50	100.0	100.0	100.0	100.0	0	0.0
1	2	56	69.6	100.0	100.0	100.0	99	1.8
2	5	120	25.8	61.7	87.4	95.8	1221	10.2
3	3	76	35.5	81.7	90.8	100.0	302	4.0
4	1	21	38.1	95.2	100.0	100.0	142	6.8
5	4	90	5.6	46.7	85.5	100.0	878	9.8
6	1	24	4.2	54.2	79.0	91.7	671	28.0
Checks	9	206	2.4	6.8	23.3	38.3	5058	24.6

Compatibility of 666 with Fungicides in Pear Psylla Sprays

Spray combinations of 666 with some common fungicides were as effective against pear psylla nymphs as 666 alone (Table 12). Refined 666 was used at 0.5 lb. per 100 gal., and it should be pointed out that as all the resulting kills were close to 100%, the possible deleterious effect of some of the fungicides may have been masked, although it is clear that from a practical standpoint this is unlikely to be of much significance.

TABLE 12.—EFFECT OF FUNGICIDES ON THE ACTION OF 666 AGAINST PEAR PSYLLA NYMPHS

Materials used per 100 gal.	Total nymphs	Percentage mortality
Refined 666, 0.5 lb. with:		
Bordeaux mixture 5-10-100	815	99.3
Dry flotation sulphur 10 lb.	562	97.2
Fixed copper (COCS)* 3 lb. with hydr. lime 3 lb.	709	97.3
Fermate†, 2½ lb.	614	99.8
Refined 666, 0.5 lb. used alone	650	98.6
Check—Not sprayed	745	4.2

*Copper oxychloride sulphate.
† Ferric dimethyldithiocarbamate.

Green Chrysanthemum Aphid (*Rhopalosiphum rufomaculatum* (Wilson))

DDT and 666 were tested against this insect by two methods: (a) plants infested with aphids were sprayed and mortality counts made 4 days later; and (b) uninfested plants were sprayed and after the deposit dried, 10 adults added per plant and the population recorded 9 days later. As a direct contact spray, crude 666 was about twice, and gamma 666 about 8 times as toxic as DDT, when all three were used as powder suspensions. It is interesting to note in Table 13 that the pure gamma 666 was only approximately 4 times as toxic as the crude 666, although the latter contained only 10 to 12% of the gamma isomer.

TABLE 13.—EFFECT OF DDT AND 666 ON GREEN CHRYSANTHEMUM APHID AS DIRECT CONTACT SPRAY ON INSECTS AND PLANTS

Lb. per 100 gal	Gamma 666		Crude 666		DDT	
	No.	Mort.	No.	Mort.	No.	Mort.
		%		%		%
0.031	587	52.5	—	—	1065	4.0
0.062	939	84.6	1765	10.0	743	10.2
0.125	1005	97.7	2197	38.6	514	38.9
0.25	882	99.6	941	61.1	149	75.2
0.5	—	—	964	94.7	—	—
1.0	—	—	547	99.6	—	—

(Check 7.8% mortality)

In the test for residual effect, where the plants only were sprayed, DDT was considerably more effective than 666. From an initial population of 30 adults per treatment the following populations resulted after 9 days: check, 216 aphids; crude 666 at 0.25, 0.5 and 1.0 lb. per 100 gal., 123, 40, and 4 aphids, respectively; and DDT at 0.25, 0.5 and 1.0 lb. per 100 gal., 9, 4, and 0 aphids, respectively. This may indicate more rapid loss of toxicity by 666 on the foliage.

Squash Bug (*Anasa tristis* (DeG.))

DDT and 666 were tested against this insect by placing adults in small cylindrical screen cages, and dusting them fairly heavily, using a small hand duster and giving the same number of puffs for each treatment. A circular slice of gourd or squash about 3 in. in diameter was similarly dusted, then the insects and the piece of gourd or squash transferred to clean cages over moist sand in flower pot saucers. The standard formula wettable spray powders (10% DDT or 666, 3% Orvus, 87% pyrophyllite) were used as dusts in most cases, diluted with pyrophyllite when necessary. An American sample of 5% 666 dust was also used.

The observation cages used for the first test were 4 in. in diameter and 5 in. high, and the kill obtained was considerably higher than in those subsequently used which were 8 in. in diameter and 1 foot high. This

difference was probably due to the fact that in the smaller cages the bugs spent more time on the treated gourd or squash, and in the case of the 666 this almost undoubtedly resulted in increased fumigant action.

In both the large and small cages refined 666 gave a more rapid and higher kill than an equal amount of DDT. Five days after treatment the results in the small cages were as follows: 10, 5 and 2.5% refined 666, 100% mortality in all cases; DDT dusts of the same concentration, 100, 83.3 and 91.6% mortality, respectively; and for the check 0%. The more rapid kill by 666 is indicated by the mortality figures two days after treatment, which were 100, 100 and 91.6%, respectively for the three 666 dusts, and 50.0, 25.0 and 8.3%, respectively for the DDT dusts.

The experiment in the large cages was a comparison of two samples of 666 with DDT. The two 666 materials, refined 666 from England, and the American sample of 666 (22% gamma isomer) were diluted to give approximately the same gamma content. The results given in Table 14 show somewhat higher kill by refined 666 from England than by the American sample, but this may be because the dilution of the refined 666 was based on a gamma content of 30%, whereas it may actually have been nearer 40%, the manufacturer having stated the gamma content to be between 30 and 40%.

TABLE 14.—COMPARISON OF DUSTS OF 666 AND DDT AGAINST ADULT SQUASH BUGS. TWENTY-FIVE BUGS PER TREATMENT

Material	Approx. gamma isomer content	Percentage mortality
	%	%
3.6 % refined 666 dust	0.1*	100
1.8 % refined 666 dust	0.55*	76
0.9 % refined 666 dust	2.275*	68
0.45% refined 666 dust	0.137*	44
5 % 666 dust (American sample)	0.1	76
2.5 % 666 dust (American sample)	0.55	68
1.25% 666 dust (American sample)	0.275	60
0.62% 666 dust (American sample)	0.137	24
10 % DDT dust	—	76
5 % DDT dust	—	67
2.5 % DDT dust	—	68
1.25% DDT dust	—	20

* Calculated on basis of 30% gamma content for refined 666.

Large Milkweed Bug (*Oncopeltus fasciatus* (Dall.))

This species was used as a test insect because it can easily be reared in large numbers on dry milkweed seed during the winter. Cylindrical test cages 4 in. in diameter and 5 in. high were made of 16-mesh wire screen and placed on racks so that air could enter through the bottom as well as through the top and sides. Each cage was provided with a tablespoonful of milkweed seeds and a moist cotton wick. As the bugs are very active,

they were immobilized by being chilled for 15 minutes in a vial plunged in ice-water, after which they were sprayed for exactly 10 seconds and at once transferred to the observation cages, 50 bugs per cage. The first test indicated that refined 666 was more than twice as toxic as DDT under these conditions, the kills for refined 666 at 0.025, 0.5, 1.0 and 2.0 lb. per 100 gal. being 70, 90, 100 and 100%, respectively after 6 days, while kills by the same rates of DDT were 3.0, 11.0, 30.0 and 72.0%, respectively.

Fumigant Action of 666

Because it was suspected that 666 was acting as a fumigant in these cages an experiment was set up in which the insects were exposed to a variety of conditions as described in Table 17, and the following points were brought out: (a) The fumes from the refined 666 spray deposit on 50 dead bugs were sufficiently toxic to kill 50 unsprayed bugs in a sealed jar, but had little or no effect in wire screen cages. (b) The same deposit on the living bugs gave a kill approaching 100% in the wire screen cage in still air, but only 5% mortality after 4 days when the cage was placed in a breeze of approximately 8 m.p.h. from a fan. (c) A spray deposit which was rapidly dried with a fan in about 5 minutes appeared to be just as toxic later in still air as one allowed to dry slowly, but a deposit kept in the breeze for 4 days appeared to have lost its toxicity entirely.

TABLE 17.—TOXICITY OF REFINED 666 1 LB. PER 100 GAL. TO MILKWEED BUGS UNDER VARIOUS CONDITIONS IN CAGES. FIFTY BUGS PER CAGE

Conditions of experiment	Percentage mortality 4 days after treatment
1. Wire screen cage in breeze from fan	5
2. Wire screen cage in still air	91
3. Wire screen cage, bugs dried quickly, then placed in still air	88
4. Fifty unsprayed bugs placed in wire screen cage containing 50 sprayed dead bugs	6
5. Fifty unsprayed bugs placed in sealed pint glass jar with 50 dead sprayed bugs	100
6. Same as 5, but dead bugs dried before being placed in glass jar	100
7. Checks, sealed jar and wire cages	0

N.B.—The dead bugs in 4, 5, and 6, were separated from the living bugs by a small wire cage within the observation cage.

Three series of tests were conducted in which the cages were placed at various distances from the fan and the wind velocity determined. Anemometer reading showed that speed of the fan varied somewhat with changes in the electric current. The insects were chilled, then sprayed for 7 seconds and at once transferred to the cages, 50 adults per cage. The spray gun delivery was greater than for the previously described tests, and this may have accounted for the relatively higher kills.

The results from the three series of tests are presented in Table 18 and show a marked reduction in the speed of kill as the wind velocity increased, although at the end of one week the differences between cages were not as great as obtained in the earlier tests. These experiments suggest that careful observations should be made in field experiments to note differences due to temperature, humidity, and particularly wind.

TABLE 18.—EFFECT OF WIND VELOCITY ON CONTACT ACTION OF REFINED 666 AT 1 LB. PER 100 GAL. AGAINST ADULT MILKWEED BUGS. FIFTY BUGS PER CAGE

Wind velocity m.p.h.		Days after treatment—percentage mortality						
Outside cage	Inside cage	1	2	3	4	5	6	7
		%	%	%	%	%	%	%
Test A								
6.91	6.34	4	8	20	—	—	—	—
6.11	5.09	4	14	48	—	—	—	—
2.36	2.04	20	30	62	—	—	—	—
1.44	0.45	62	80	90	—	—	—	—
1.06	Trace	62	80	86	—	—	—	—
0.79	Trace	36	68	76	—	—	—	—
Trace	Trace	78	84	94	—	—	—	—
Zero	Zero	100	100	100	—	—	—	—
Test B								
3.05	1.74	24	24	26	60	80	94	96
1.90	1.25	28	28	34	70	90	96	98
1.27	0.92	50	52	76	86	90	94	94
0.81	Trace	72	78	84	98	98	100	100
Trace	Trace	72	88	96	98	98	100	100
Trace	Trace	78	92	92	96	98	100	100
Trace	Trace	96	100	100	100	100	100	100
Trace	Trace	100	100	100	100	100	100	100
Test C								
8.31	5.86	8	24	52	70	80	86	88
4.72	2.76	10	36	72	76	78	80	86
2.24	0.85	18	54	82	88	96	96	98
1.05	0.11	82	90	98	100	100	100	100
0.45	Trace	84	90	96	96	98	98	98
Trace	Trace	86	96	96	96	98	98	98
Zero	Zero	88	100	100	100	100	100	100

Unsprayed check in still air—zero mortality after one week

Chrysanthemum Thrips (*Thrips nigropilosus* Uzel.)

A few observations made on the control of these thrips on the chrysanthemum plants sprayed for aphid tests, indicated that crude 666 is toxic to this species, but less so than DDT, e.g., all nymphs were eliminated by DDT at rates as low as 0.125 lb. per 100 gal. (wettable spray powder suspension), while a similar spray of crude 666 at the same rate reduced the population by approximately 80%. No information was obtained on the residual effect of 666.

European Red Mite (*Paratetranychus pilosus* (C. & F.))

No test with 666 was made specifically against this mite, but thriving populations developed in the insectary on potted apple seedlings which had been sprayed with 666 at high concentrations.

Common Red Spider Mite (*Tetranychus telarius* (Linn.))

In a test where crude 666 was used at 0.25, 1.0, and 4 lb. per 100 gal. kills of red spider mite of 3.2, 21.4, and 43.9%, respectively resulted on rose plants, while pure gamma 666 at 0.5 and 1 lb. per 100 gal. killed 50.1 and 72.1%, respectively on cucumber, indicating that the material is of little value against this mite.

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INFLUENCE OF DDT ON YEAST FERMENTATION[1]

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The Dominion Entomological Laboratory at Vineland, Ontario, carries on extensive experiments on the control of insect pests with the aid of dichloro-diphenyl-trichlorethane, commonly known as DDT. One of their problems is the control of insect pests in the vineyard. Naturally they were interested in knowing if DDT has a detrimental effect on yeast fermentation. Therefore at the request of W. A. Ross, Chief, Fruit Insect Investigations, this experiment was carried out.

In a compaıatively short time a voluminous literature has been accumulated on the subject of control of insect pests by use of DDT sprays. However, so far as the author is aware, there is no published record dealing with the influence of DDT on yeast fermentation. Surveying the literature on the subject of the activity of DDT against microorganisms it was found that Granovsky (1), working on control of insects on potato plants, reported that plants dusted with DDT were somewhat less affected by leaf parasitic fungi than the plants of control plots. Morris (2), however, carrying experiments *in vitro* and with soil under greenhouse conditions, was unable to control the growth of *Ophiobolus graminis*, *Colletotrichum trifolii*, *Ascochyta imperfecta*, *Pleospora herbarium*, *Pseudoplia trifolii*, *Urocystis tritici* and damping off organisms with the aid of DDT. Furthermore, Abbott (3) reported that 105 mg./ml. of DDT in the medium did not affect the growth of *Physarella oblonga*. However, when DDT was applied in powdered form on the surface of the medium the growth of the same organism was to a certain extent delayed as compared with the growth on control plates. The delay in growth was attributed to mechanical reasons.

In this laboratory previous experiments indicated that 217 mg. per cent DDT in the medium did not affect the growth of *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhimurium*, *Blastomyces Gilchristi*, *Microsporon lanosum* and *Trichophyton gypseum*. Furthermore, it was noticed that when required amounts of DDT were dissolved in ethanol and added to an agar medium, crystals formed in the majority of cases, after evaporation of alcohol and cooling of agar. In these cases the fungi and bacteria were able to grow normally in direct contact with crystals of DDT. Negative results were also obtained when DDT was added to the medium in oil solutions (mineral and vegetable, soybean). In this case the organisms were able to grow (mycelium) through or on the oil droplets.

In this report the influence of DDT on yeast fermentation is presented and discussed.

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Experiment 1

RESULTS

The organism *Saccharomyces ellipsoideus* was grown in the following medium: urea, 0.1 gm.; grape juice concentrate, 30.0 gm.; commercial refined cane sugar, 19.3 gm.; distilled water, 171 ml. Fifteen flasks, each containing 200 ml. of the medium, were prepared, 9 flasks receiving the following amounts of DDT:

Flask No.	Weight of powder	Weight of DDT
	gm.	gm.
1	0.0210	0.0021
2	0.0420	0.0042
3	0.0630	0.0063
4	0.0940	0.0094
5	0.1050	0.0105
6	0.1580	0.0158
7	0.2100	0.0210
8	0 3150	0.0315
9	0.4200	0.0420

The powder consisted of diatomaceous earth containing 10% DDT ground in a ball mill to colloidal texture.

Six flasks were kept as controls. After addition of DDT the flasks were autoclaved at 15 lb. pressure for 20 minutes, cooled and inoculated with 5 ml. yeast suspension, except the last 2 flasks (14 and 15) which were kept as uninoculated controls. The flasks were then weighed and incubated at 22 to 24° C.

The original sugar content in the media was determined by refractometer, and as fermentation progressed the sugar content was maintained at 7% by the constant weight method by addition of 50% sugar syrup. The incubation was discontinued on the 10th day and results of this experiment are summarized in Tables 1, 2, and 3. The results obtained do not indicate outstanding differences as among DDT treated media if compared with control media. If, however, we compare the average daily loss in weight per day of 9 DDT treated media with average daily loss of control media (Table 2) we note that the intensity of fermentation during the first 5 days of incubation was depressed by the addition of DDT (weighing began on the 3rd day of incubation). However, during the last 5 days of incubation the fermentation was more vigorous in DDT treated media than in controls.

Data presented in Table 1 also indicate the considerable variation in yield of alcohol as expressed in per cent by volume. However, the general trend in yield of alcohol indicates a gradual decrease in yield with increasing amounts of DDT added to the medium. The average yield of alcohol per flask of DDT treated media is lower than the average yield in control media. However, if DDT treated media are divided into two lots. the first consisting of first 4 flasks to which the amount of DDT added was from 2 to 9 mg. and second lot from 10 to 42 mg. per 200 ml. of medium, and the average yield of alcohol produced compared, we then note that the production of alcohol in the first lot is equal to that of the control media,

TABLE 1.—EFFECT OF DDT ON DAILY AND TOTAL CONSUMPTION OF SUGAR DURING FERMENTATION AND ON ALCOHOL PRODUCTION

Treatment	Time of incubation—days, Loss in weight—grams: 3	4	5	6	7	8	9	10	Total loss per sample, gm.	Average loss, gm.	Total sugar consumed, gm.	Average sugar consumed, gm.	Yield alcohol percentage by volume	Average yield of alcohol percentage by volume
DDT added														
1	0.50	0.80	4.55	2.75	4.70	1.00	0.20	0.15	14.65		34.15		10.86	Average of
2	0.55	1.10	5.45	2.55	4.35	0.80	0.20	0.15	15.15		34.51		10.80	4 treatments
3	0.65	1.50	5.50	2.85	3.70	0.40	0.15	0.15	14.90		34.33		10.86	10.80 10.68
4	0.80	1.75	6.20	2.85	2.95	0.25	0.15	0.10	15.05		34.34		10.69	
5	0.95	2.00	6.65	2.70	2.65	0.20	0.00	0.05	15.20	15.05	34.49	34.41	10.61	Average of
6	0.85	1.65	5.90	3.55	2.65	0.25	0.05	0.00	14.90		34.40		10.63	5 treatments
7	0.50	1.50	6.40	2.95	3.60	0.20	0.15	0.00	15.30		34.59		10.61	10.58
8	0.35	1.05	5.90	2.75	4.55	0.35	0.15	0.05	15.15		34.44		10.61	
9	0.45	1.35	6.20	2.60	4.10	0.30	0 10	0.05	15.15		34.44		10.44	
Control inoculated														
10	0.80	1.40	5.20	2.35	3.95	0.80	0.15	0.10	14.75		34.18		10.69	
11	1.40	2.15	5.75	2.45	3.05	0.30	0.20	0.20	15.50		34.79		10.81	
12	0.70	1.70	7.30	2.45	3.00	0.15	0.15	0.05	15.50	15.21	34.86	34.55	10.86	10.80
13	0.75	1.65	6.75	2.60	2.85	0.30	0.20	0.00	15 10		34.39		10.84	
Control not inoculated														
14	—	—	—	—	—	—	—	—	—	—	—	—	—	
15	—	—	—	—	—	—	—	—	—	—	—	—	—	

Original sugar content of medium = 17.1% by volume.
Sugar content in fermented juice = 7% by volume.

TABLE 2.—EFFECT OF DDT ON DAILY LOSS IN WEIGHT OF MEDIA DURING FERMENTATION

Incubation days	DDT treated media		Control media	
	Average loss—gm.		Average loss—gm.	
	Daily	5 Days	Daily	5 Days
3	0.62		0.91	
4	1.41		1.72	
5	5.86	1.58	6.25	1.76
6	2.84		2.46	
7	3.69		3.21	
8	4.17		3.90	
9	0.22		0.18	
10	0.08	2.20	0.09	1.89

TABLE 3.—EFFECT OF DDT ON ALCOHOL PRODUCTION COEFFICIENT*

Treatment	Sugar consumed, gm.	Volume fermented juice, ml.	Yield of alcohol, ml.	Alcohol production coefficient	
				Per treatment	Average
1	34.15	210	22.81	66.79	4 treatments
2	34.51	212	22.90	66.36	66.55
3	34.33	211	22.92	66.73	
4	34.34	213	22.77	66.31	
5	34.49	213	22.60	65.53	5 treatments
6	34.40	210	22.32	64.88	65.17
7	34.59	213	22.60	65.34	
8	34.44	213	22.60	65.62	9 treatments
9	34.44	213	22.24	64.58	65.79
10	34.18	211	22.56	66.00	
11	34.79	213	23.03	66.20	66.35
12	34.86	212	23.02	66.04	
13	34.39	213	23.09	67.14	

* $K = \dfrac{\text{total yield of alcohol, ml.}}{\text{total consumption of sugar—grams}} \times 100.$

whereas production of alcohol in the second lot is somewhat lower than in the controls. Furthermore, if the "production coefficient" is calculated from data obtained, that is production of total alcohol ml., per gram of sugar consumed, it will be seen (Table 3) that the production coefficient is gradually decreased with increasing amounts of DDT added. However, if the average production coefficient is calculated for the first 4, and for the last 5 DDT treated media, and compared with the average production coefficient of the controls, it will be evident that production coefficient of the first lot is higher and that of the second lot lower than the average production coefficient of control flasks. This would indicate that addition of not more than 10 mg. of DDT per 200 ml. of medium will create a condition more economical for production of alcohol.

Experiment 2

Grapes sprayed with DDT and grapes sprayed according to the regular schedule with lead arsenate, were received from the Entomological Laboratory, Vineland, Ontario, for experimental purposes. The plots had been sprayed three times during the season, the rate of application being 1½ half lb. of actual DDT per acre of vineyard. Therefore the total weight of actual DDT in three sprays amounted to 4½ lb. per acre.

It was impossible to arrange the experiments immediately on arrival of the shipment. For this reason the grapes were stored in the basement for 15 days prior to using them in experiments.

On examination of the samples after storage and during the preparation for fermentation it was noticed that DDT sprayed grapes were less damaged or contaminated with moulds (chiefly *Penicillia*, *Phycomycetes* and *Aspergilli*) than the control sample.

Samples were prepared for fermentation as follows: (1) 2600 gm. grapes from each treatment, in duplicate, were crushed by hand and deposited separately into 10-l. flasks; (2) each flask received 370 gm. refined cane sugar and 1477 ml. of tap water. Each flask was inoculated with 100 ml. actively fermenting medium. The inoculum was started in sterile medium of the same composition as in the case of the first experiment, by inoculation with *Saccharomyces ellipsoideus*. Sugar content of the fermenting grape juice was determined by the Brix method, by subtracting 2 from the Brix reading for non-sugar soluble solids. The sugar content of the fermenting juice was maintained at 7% throughout the experiment by addition twice daily (early stage of fermentation) of cane sugar. The flasks were incubated at room temperature, with daily fluctuation of temperature between 70 and 80° F. Weights of fermenting juice and weights of daily addition of sugar are presented in Tables 4 and 5.

At the end of fermentation (13 days) total volume and weight of fermented juice of each sample were determined. Alcohol per cent by volume, and per cent of total and volatile acids were determined by the official A.O.A.C. methods. Results are summarized in Tables 4, 5 and 6.

The average percentage of alcohol by volume and total yield of alcohol per cent by volume produced by DDT sprayed grapes are lower than in the control samples, whereas the percentages of total and volatile acids are slightly higher, 0.015 and 0.003, respectively, than in control samples.

The intensity of fermentation, as indicated by daily addition of sugar, in flasks with DDT sprayed grapes was to a certain degree retarded at the beginning of the experiment, and was more vigorous at the end of the experiment as compared with the control grapes. The alcohol production coefficient for DDT sprayed grapes is again higher than for control grapes. In general the results of this experiment are in agreement with results obtained from the first experiment, except that the production coefficient in this case is only approximately half as high as in the first experiment. The content of DDT in fermented grape juice has been determined by the Division of Chemistry, Department of Agriculture; according to their report no DDT was found in the fermented juices. The sensitivity of the method used was less than 2 mg. per 100 ml. of the fermented grape juice.

TABLE 4.—DAILY LOSS IN WEIGHT OF MEDIA WITH DDT SPRAYED GRAPES AND MEDIA WITH GRAPES SPRAYED WITH LEAD ARSENATE (CONTROL)

Treatment	Time of incubation—days													Total loss
	1	2	3	4	5	6	7	8	9	10	11	12	13	
	Daily loss—grams													gm.
DDT spray I	0	46	203	69	115	184	138	10	112	50	65	25	24	1041.0
DDT spray II	0	124	226	55	148	184	138	56	89	10	106	35	20	1191.0
Average	0	85	214.5	62	131.5	184	138	33	100.5	30	85.5	30	22	1116.0
Control I	156.3	134	194	78	102	115	115	33	20	80	56	10	13	1106.3
Control II	78.2	202	194	78	125	125	125	56	66	50	60	20	10	1189.2
Average	117.3	168	194	78	113.5	120	120	44.5	43	65	58	15	11.5	1147.8

TABLE 5.—CONSUMPTION OF SUGAR IN FERMENTATION OF DDT SPRAYED GRAPES AND GRAPES SPRAYED WITH LEAD ARSENATE (CONTROL)

Treatment	Before fermentation			After fermentation			Sugar added during ferment., gm.	Total sugar consumed, gm.
	Wt. of sample, gm.	Sugar per-centage (Brix)	Calcul. wt. of sugar per sample, gm.	Wt. of ferment. juice, gm.	Sugar percentage (Brix)	Sugar not ferment., gm.		
DDT spray I	4600	18.0	828.0	4110	6.30	258.9	1041.0	1610.1
DDT spray II	4600	17.8	818.8	4250	6.20	263.5	1191.0	1746.3
Control I	4600	17.5	805.0	4210	6.20	261.0	1106.3	1650.3
Control II	4600	17.6	809.6	4250	6.55	278.4	1189.2	1720.4

TABLE 6.—ALCOHOL PRODUCTION BY FERMENTATION OF DDT SPRAYED GRAPES AND GRAPES SPRAYED WITH LEAD ARSENATE (CONTROL)

Treatment	Volume fermented, juice, ml.	Total acids, %	Volatile acids, %	Alcohol per-centage by volume	Yield alcohol, ml.		Sugar consumed, gm.	Alcohol product. coefficient*	
					Per treat.	Average		Per treat.	Average
DDT spray I	4180	0.61	0.070	13.34	557.6	555.25	1610.1	34.63	33.15
DDT spray II	4280	0.60	0.070	13.01	552.9		1746.3	31.66	
Control I	4210	0.58	0.067	13.35	562.1	556.85	1650.3	34.06	33.06
Control II	4220	0.61	0.067	13.07	551.6		1720.4	32.06	

* $K = \frac{\text{Yield of alcohol, ml.}}{\text{Sugar consumed—grams}} \times 100.$

DISCUSSION

The results of the first experiment indicate no outstanding difference in the production of alcohol or consumption of sugar during the process of fermentation due to the addition of different amounts of DDT to the medium. Furthermore, no striking differences have been obtained in the production of alcohol by DDT treated and control media. However, minor differences, such as lag in intensity of fermentation during the first 5 days of incubation in DDT treated medium, slightly lower production of alcohol in per cent by volume or slight differences in production of alcohol per gram of sugar consumed, were evident.

Because of the fact that a control with diatomaceous earth alone was not included in the first experiment, there is no definite proof that the delay in the intensity of fermentation was due to the mechanical or chemical effect of DDT or due to the mechanical action of diatomaceous earth. However, when grapes sprayed with DDT were used for alcohol production, a similar trend of fermentation was noted. In this case diatomaceous earth was not included in the spray formulae. Therefore the delay in intensity of fermentation may be attributed to the influence of DDT in powder or in spray form on the intensity of fermentation during the first 5 days incubation.

SUMMARY

An investigation has been made of the effect of DDT on yeast fermentation by comparing the volume of alcohol produced by the yeast in DDT treated and control media. The production of alcohol from DDT sprayed grapes in comparison with alcohol production from control (sprayed with lead arsenate) grapes was also investigated.

DDT treated media containing from 5 to 20 mg. per cent of actual DDT showed 2.96% reduction of alcohol production, expressed in per cent by volume, and 1.96% reduction in total yield of alcohol, if the production of alcohol in control media was taken as 100. However, when media contained less than 5 mg. per cent DDT the production of alcohol was the same as in control media.

Production of alcohol per gram of sugar consumed was not affected by the addition to the medium of up to 5 mg. per cent of actual DDT, whereas addition of more than 5 and up to 21 mg. per cent, resulted in 1.78% reduction when production in control media is expressed as 100.

The intensity of fermentation in DDT treated media was retarded during the first 5 days incubation; however, this delay was largely compensated for during the following days of incubation.

In general similar results have been obtained when grapes sprayed with DDT for control of insect pests were used for alcohol production.

According to chemical analyses no DDT was detected in the fermented grape juice obtained from DDT sprayed grapes.

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ALFALFA SEED PRODUCTION IN NORTHERN SASKATCHEWAN AS AFFECTED BY LYGUS BUGS, WITH A REPORT ON THEIR CONTROL BY BURNING[1]

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In the period 1941-44 a series of investigations was carried out on the effects of various insects on alfalfa seed production in the White Fox district of northern Saskatchewan. Other publications (4, 5) have discussed relationships between honey bees and wild bees, and seed setting; these contained a general description of the history and natural vegetation of the area. This study was intended to deal with injurious insects belonging to the genera *Adelphocoris* Reut. and *Lygus* Hahn[4]. Members of both genera have been reported as attacking alfalfa in the northern portions of nearctic America. Hughes (2) found *A. lineolatus* Goeze and to a much lesser extent *A. rapidus* Say, of prime importance in northern Minnesota, and their prevalence in the White Fox area should be mentioned. However, *A. lineolatus* was not found and *rapidus*, although widely distributed throughout the area, was not numerous enough to be considered of economic importance. Hence, further reference will concern *Lygus* only, and particularly *L. hesperus* Knt. and *L. elisus* Van D.

DESCRIPTION AND DISTRIBUTION

An excellent description of these two species of *Lygus* is given by Sorenson (9). The adults vary in size from 5/32 to 3/16 inch in length and about one-half that in width, and in colour from a pale green to a dark brown. They are strong-winged insects and overwinter as adults, presumably among the debris in fields and waste places. Egg-laying starts early in the season. The nymphs pass through five instars before the adult stage is reached. They are wingless, yellowish- or bluish-green, and in size and colour the earlier stages resemble young aphids but are readily distinguished from the latter by their ability to run about rapidly, by shorter and sturdier legs, and by harder bodies. In the later stages the developing wing pads are characteristic of the lygus bugs. In southern Alberta, Salt (6) reports two generations per season. No definite studies on this point were conducted in the White Fox area. However, in 1944 nymphs were rare in samples taken June 7 and 8 and adults were not numerous until about July 15. Even from July 31 to August 3, when a series of 21 fields was sampled, only 27% of the population was adult. As these data correspond closely to Salt's, and as few of the second generation matured at Lethbridge until September, it can reasonably be assumed that at White Fox the lower temperatures, which usually included at least a light frost by the middle of August, would result in few or no lygus bugs reaching maturity from the second generation.

The distribution of *Lygus* spp. attacking alfalfa is widespread. *L. oblineatus* Say is common in the eastern United States and Hughes (2)

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[1] Contribution from the Division of Forage Plants, Experimental Farms Service and Contribution No. 2402 from the Division of Entomology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.
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[4] The specific names in these genera follow the arrangement of Knight (3).

found it the most common species in northern Minnesota. Westward from Illinois, Iowa and Minnesota *hesperus* and *elisus* occur and Sorenson (9) and Carlson (1) in Utah, and Salt (6) in southern Alberta, record them as being common in alfalfa fields. In the White Fox area *hesperus* and *elisus* appeared to be the principal species.

HOST PLANTS AND NATURE OF DAMAGE

No extensive study of host plants was made but both *L. hesperus* and *elisus* are native to northern Saskatchewan and were found sparsely present whenever the native vegetation was sampled. They were found rarely in cultivated fields of oats, barley, flax and field peas in the White Fox district but counts of as high as 9.7 per sweep were recorded on an area heavily grown to lambsquarters, *Chenopodium album* L.

The two species are difficult to distinguish and at the time this study was made no differences had been established between the damage caused by each species. Thus they were grouped as *Lygus* spp. in the field data recorded. However, Stitt (11) has since shown that in California *L. hesperus*, when compared with *elisus*, can cause a slightly greater amount of flower·fall and a highly significant increase in the number of non-viable brown seeds.

In all stages of development lygus bugs feed by sucking the juices from the host plant. Damage to alfalfa is chiefly to the growing parts and can be recognized through bud-blasting, flower fall and injury to both pods and seeds. Bud-blasting is the withering of the buds and the formation of so-called "white-tops"; flower fall is obvious in heavily infested fields, and injury to the developing seed results in the seed being brown in colour and more or less shrivelled. These symptoms are not always entirely due to lygus bugs and may be caused by factors such as climatic conditions, lack of fertilization, and injury from other insects such as thrips and the clover seed chalcid. However, Sorenson (7, 8, 9) and Stitt (10) have definitely related them to the prevalence of lygus bugs, and the large numbers of lygus bugs in the fields of alfalfa around White Fox leave no doubt as to their being the principal cause of seed damage as described later in this paper.

SURVEY OF BUG POPULATION

During each of the four years 1941 to 1944 a general survey of alfalfa fields in the White Fox area was made to obtain some idea of the general population of lygus bugs in that district. Table 1 presents a summary of the data based upon the average number of bugs taken by sampling with an insect net 14 inches in diameter. Each sweep was approximately 5 feet in length and taken with the man facing as nearly as possible into the wind and towards the sun. In recording data the numbers of adults and nymphs were not kept separate except in 1944 when, as previously stated, the samples contained an average of 27% adults. It was not always possible to sample at the same date period in each year. However, sampling was done at a time when serious damage could occur; that is, either when the crop was in full bloom and setting seed or after full bloom but before the pods had reached maturity.

TABLE 1.—AVERAGE FIELD POPULATIONS OF LYGUS BUGS IN DIFFERENT YEARS IN ALFALFA FIELDS IN THE WHITE FOX AREA

Year	Date	No. fields examined	No. of bugs per sweep*		Fields having 5.01–9.50 bugs per sweep	Fields having over 9.50 bugs per sweep
			Average	Range		
					%	%
1941	July 18–24	11	9.23	3.8–16.3	18	64
1942		33	0.45	—	—	—
1943	Aug. 15–18	27	6.17	0.8–18.4	30	26
1944	July 31–Aug. 3	21	13.52	2.5–50.0	21	54

* Total of adults and nymphs.

In California and Arizona, Stitt (10) found that a population of 5.01 to 9.50 lygus bugs per sweep resulted in a fall of 34.91% of the flowers that normally would form pods. For more than 9.50 bugs per sweep the value he obtained was 53.89%. If these relationships between lygus bug populations and flower fall hold in the White Fox area, then it is evident from Table 1 that losses in 1941, 1943 and 1944 were of serious proportions. As shown later in this paper, subsequent damage to developing seed undoubtedly also affects the seed yield of alfalfa. The reason for the light infestation in 1942 is not known. However, an exceptionally light snowfall during the winter of 1941-42, followed by a wet summer, may have caused a sharp reduction in the survival and propagation of lygus bugs.

EFFECT OF AGE OF STAND ON *Lygus* POPULATIONS

In 1943 a record was kept of the age of the stand of all 27 fields examined in the general survey summarized in Table 1; 13 of these fields were producing their first crop of seed, and 14 (which were producing the second, third or fourth crop) were grouped for the comparison with first crop stands.

The average number of lygus bugs per sweep was 3.6 (0.8 to 12.0) on the first crop stands and 8.5 (4.1 to 18.4) for the older stands. However, the 2 highest counts (12.0 and 6.6) in the first crop stands were on fields that had been seeded without a nurse crop in 1942 and had consequently made a heavy growth that year. The remaining 11 fields of first crop stands had been seeded with a nurse crop of cereals or flax and had not made nearly as vigorous a growth. As one might expect, the populations of lygus bugs increased more rapidly both in the pure stands of alfalfa in the fields seeded without a nurse crop and in the older fields than in the stands seeded with a nurse crop.

BROWN AND SHRIVELLED SEED AS RELATED TO LYGUS BUGS

The percentage of brown and shrivelled alfalfa seed has been shown by Sorenson (8) to be proportional to the lygus bug infestation, and Hughes (2) noted that badly shrivelled brown seed seemed of little value and that less than one-third of it germinated normally.

Since this type of seed is common in samples from northern Saskatchewan, 19 fields were sampled in 1944. The population of lygus bugs in each field had been estimated previously in the general survey summarized in Table 1. The seed samples were collected by walking through each field and picking ripe pods at random until a sample representative of the field had been gathered. Since frost damage is known to discolour alfalfa seed, all collections were made before early fall frosts had occurred. The samples were later threshed by hand and the seed separated so that even very small, shrivelled seeds were retained. The total number of seeds in each sample was counted and the "brown and shrivelled portion" recorded as a percentage of the total number.

The average proportion of brown and shrivelled seeds for the 19 fields sampled was 22% with a range from 9 to 51%. The average number of bugs per sweep for the same fields was 15 with a range from 2 to 50. When the two values from each field were correlated a correlation coefficient of + .58 was obtained. This value exceeds the 1% point.

A further study concerned the viability of different classes of seed. The economic value of these grades was measured by testing their viability at the Plant Products Laboratory at Saskatoon. As previously stated, the threshed seed was divided into a normal, and a brown and shrivelled, portion. This latter class was then subdivided by means of an air blast into heavy and light fractions. Table 2 presents a summary of the data obtained.

TABLE 2.—RELATIVE WEIGHTS AND PERCENTAGE GERMINATION OF NORMAL AND BROWN AND SHRIVELLED ALFALFA SEED

Class of seed	Percentage of original sample	Relative weight in percentage	Percentage germination, including hard seeds
	%	%	%
Normal	78	100	93
Brown and shrivelled Heavy fraction	7	90	26
Light fraction	15	48	3

The heavy fraction consisting of 7% of the total should correspond closely to the brown seed found in cleaned and graded samples undamaged by frost. The lighter fraction probably would be almost entirely blown over or screened out in normal threshing and cleaning processes.

From the data presented it is concluded that the brown and shrivelled alfalfa seed found in these samples was caused largely by lygus bugs and that its viability was low. The average of 22% of defective seed indicates a considerable reduction in yield and, since the range was from 9 to 51%, the loss was very high in individual fields.

CONTROL METHODS

The use of a pyrethrum concentrate and sulphur has been reported by Carlson (1) to have given increased yields on small plots. Sorenson (9)

considered the use of various insecticides insufficiently effective to be considered a practical means of control under field conditions. Hughes (2), however, found that pyrethrum dust had more knockdown than killing effect.

Leaving the second cutting of alfalfa for the seed crop has been suggested as a control by Sorenson (9) but this is impractical in northern Saskatchewan. Even when the first crop is allowed to set seed, serious damage from early fall frosts occurs in certain seasons. Thus any practice which delays the maturity of the crop increases this frost hazard.

Hughes (2) reported more or less control of *Lygus* spp. by certain cultural methods. Some of his data are briefly summarized as follows:

Untreated field	95.06 bugs per 50 sweeps
Thoroughly burned fields	23.62 bugs per 50 sweeps
Partially burned fields	67.97 bugs per 50 sweeps
Cultivated fields	65.00 bugs per 50 sweeps
Burned and cultivated fields	50.05 bugs per 50 sweeps

Carlson (1) has also reported an increased seed yield from a field where the dry grass was burned following the removal of the first hay crop. It has been a general custom in fairly recent years for certain alfalfa seed growers in the White Fox area to burn their fields early in the spring before little if any new growth appeared above the ground. No scientific basis was known to them for this procedure but it was generally believed that such fields gave an increased yield of seed. Burning in the fall and burning new stands were considered poor practices since both were often followed by winter-killing; burning late in the spring after the alfalfa was two or three inches high was also avoided since it delayed maturity. In most years the last two weeks of April was the best period to burn. It is not always possible to effect a complete burn, and unburned patches or strips often remain as a probable source of re-infestation. However, a heavy combine stubble and favourable weather may result in a fire that will sweep across a field in a very short time. The shorter stubble and lack of straw on fields harvested with a binder makes burning more difficult.

In 1943 a number of partially burned fields were observed and it was noted that areas of good seed-setting coincided with burned areas almost to a line, even though the edges often were very irregular. Following these observations a number of fields with patchy burns were studied in 1944. The samples for lygus bugs were based upon the average of 40 sweeps each from the burned and unburned parts of each field. Seed yields were secured from 10 paired samples of 1 square yard each. In all yield comparisons, samples were located not more than 2 rods apart and in many instances were within 10 feet of each other. The areas sampled in each field were subject to the criticism that differences, particularly in seed yield, may have been caused by the fertilizing effects of the ash residue or by favourable soil and moisture conditions which might have developed a heavier growth in the previous season and which consequently might be more likely to burn. It is not believed that either of these factors was effective. Certainly they could not account for differences in bug populations in adjacent areas. Observations on height and vegetative vigour indicated no difference in favour of the burned area. Soil type and moisture

appeared to be essentially the same and the amount of fertilizer per acre in in the ash from 1 to 1½ tons of vegetation is very small. Although spring burning is also a control for thrips, yet the numbers of thrips present seemed too small to greatly affect seed yield; definite studies on this point were not made.

A summary of the data obtained on the relationship between lygus populations and seed yield on burned and unburned areas in alfalfa fields in the White Fox area in 1944 is presented in Table 3.

TABLE 3.—LYGUS POPULATIONS AND SEED YIELDS ON BURNED AND UNBURNED AREAS IN ALFALFA FIELDS IN THE WHITE FOX AREA—1944

Field number	Average number of lygus bugs per sweep				Seed yields in pounds per acre			
	Date sampled	Burned	Unburned	Ratio of burned to unburned	Burned	Unburned	Difference	Percentage difference
1	June 7	0.5	0.3	1 : 0.6				
	June 28	3.3	8.7	1 : 2.6				
	July 5	12.0	20.3	1 : 1.7	86	36	50**	139
2	June 7	0.6	0.2	1 : 0.3				
	June 28	4.1	7.7	1 : 1.9				
	July 4	5.6	10.3	1 : 1.8	115	61	54**	89
3	June 8	0.4	0.2	1 : 0.5				
	June 28	2.8	4.9	1 : 1.8				
	July 18	7.6	8.5	1 : 1.1	127	74	53**	72
4	June 8	0.4	0.6	1 : 1.5				
	June 28	2.3	4.3	1 : 1.9				
	July 18	3.4	4.7	1 : 1.4	132	99	33	33
5	June 7	0.6	0.2	1 : 0.3				
	July 4	8.0	10.9	1 : 1.4	130	116	14	12
6	June 28	0.9	7.4	1 : 8.2				
	July 4	4.0	8.6	1 : 2.2	44	47	−3	−6
7	June 28	2.3	6.2	1 : 2.7				
	July 4	6.0	8.4	1 : 1.4				
8	July 4	4.1	7.6	1 : 1.8				
9	July 4	3.7	9.8	1 : 2.6				

** Exceeds the 1% point (odds in excess of 99 : 1).

Of the fields studied and listed in Table 3 there was no marked delay in the maturity of the alfalfa as a result of burning in any field except No. 6. This field was burned in May after the plants had made considerable growth. Consequently, it was set back 2 to 3 weeks in blossoming period and, had the fall season not been favourable, it might well have shown a greater reduction in seed yield because of frost damage. Fields No. 4 and 5 do not show a significant increase in seed yield. However, these fields were difficult to sample because the burning was irregular and the stands were patchy. In the remaining 3 fields it was easy to obtain comparable samples.

Of the 5 fields sampled on June 7 and 8 for lygus bugs, two, No. 1 and 3, showed only adult bugs. About 16% of the bugs in the other 3 fields were found to be nymphs. The total number of bugs present in any field at this time was small and did not consistently favour either the burned or the unburned areas. Evidently migration of over-wintered adults had occurred from the unburned areas after the alfalfa on the burned areas had developed sufficiently to provide food and shelter.

An altogether different picture had developed by the time later samples were taken from June 28 to July 18. The adults formed a very small percentage of the population, usually less than 5%. No counts were taken of the different instars among the nymphs but it was noticeable that the later stages were more numerous in samples from unburned areas. Thus it appears that a heavier and earlier deposition of eggs was made on the unburned patches as compared to adjacent burned stubble.

In order to interpret the data recorded on the differences in lygus populations between comparable burned and unburned areas, it is necessary to consider the situation at, and immediately following, burning. In April and early May, when the burn is effected, the alfalfa usually has made from 1 to 2 inches of growth which is entirely destroyed by the fire.

This growth may have already received some lygus eggs although no data on this point are available. If so, then the burning would have three main effects: (1) destruction of eggs, (2) destruction of adults trapped by the fire, and (3) destruction of all surface material so that neither food nor shelter would be available for a period of at least a few days. Normal egg-laying in the adjacent unburned patches would account for the more mature stages later found in the samples from these areas. Further, since food and shelter would not be present on the burned area, a concentration of adults might be expected in the unburned patches with a consequent heavier deposition of eggs, resulting in the higher numbers of nymphs recorded later in the season. As growth developed in the burned areas it is likely that there was an equalization of the numbers of the original adults, as well as of adults emerging from the nymphal stages, with respect to the two areas. This explanation agrees with the data and with observations made during the season; it also emphasizes the need for thorough burning.

As noted earlier in this discussion, the maturity of field No. 6 was delayed by late spring burning. In the other fields burning early in the spring did cause a slight initial set-back where growth had started. However, these latter fields had recovered completely by flowering time. Higher soil temperatures in the bare soil following burning, because of the greater absorption of the sun's rays, may account for the rapid recovery.

SUMMARY

1. Populations of *Lygus* spp. seriously affect seed yields of alfalfa in certain years in the White Fox area of Saskatchewan.

2. Fields producing the first seed crop tend to have lighter infestations of lygus bugs as compared to fields producing the second or later crop.

3. A significant positive correlation was obtained between the number of lygus bugs in a field and the percentage of brown and shrivelled seed taken before frost damage had occurred. This defective seed had a very low viability.

4. The reduction in lygus populations following burning of the stubble in early spring is thought to be effected by the destruction of hibernated adults, of their food and shelter, and of their eggs on the new growth of alfalfa.

5. Early spring burning of alfalfa fields is offered as a practical control measure for lygus bugs. Late spring burning should be avoided since it may seriously delay the maturity of the crop.

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THE POTATO-ROT NEMATODE, *DITYLENCHUS DESTRUCTOR* THORNE, 1945, ATTACKING POTATOES IN PRINCE EDWARD ISLAND[1]

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In 1931 potatoes coming from Prince Edward Island and New Brunswick were intercepted entering the United States. Injured tubers were submitted to Dr. G. Steiner, Division of Nematology, Washington, and the cause of the trouble found to be due to attack by the bulb or stem nematode, *Ditylenchus dipsaci* (Kuhn, 1857) Filipjev 1936. (1). This was the first time this nematode species had been found attacking the potato on the continent, although it had been recorded from this host plant in Europe.

On October 26, 1943, diseased potatoes were collected near Aberdeen Idaho, U.S.A. (2, 3). Nematodes recovered from these tubers were identified as *Ditylenchus dipsaci*. This was the first record of this nematode species attacking the potato in the United States.

In the past the "bulb or stem nematode" has been recorded from a large number of host plants and it has been evident for some time that a number of "strains" of this species existed. It was observed that populations of these different strains tended to have their own particular host range and it was suspected, by some workers, that several distinct species were involved.

The nematodes collected from Idaho potatoes were subjected to critical study by Mr. Gerald Thorne, Division of Nematology, U.S. Department of Agriculture, with the result that taxonomic characters were revealed which resulted in his naming and describing this form as a distinct species, *Ditylenchus destructor* (4). For this species Thorne suggests the common name of "potato-rot nematode". The diagnosis of *Ditylenchus dipsaci* was emended and referred to as the "teasel nematode". With further research Thorne hoped that it would be possible to definitely separate certain other forms of what was commonly known as the bulb or stem nematode.

In late November, 1945, during the course of inspection of potato stock in Prince Edward Island, Mr. G. C. Ramsay, Seed Potato Inspector, Division of Plant Protection, observed potato tubers which appeared to show some of the symptoms of bacterial ring rot. Specimens were collected and turned over to Mr. S. G. Peppin, District Inspector-in-charge, Mr. F. M. Cannon, Division of Entomology, and Mr. R. R. Hurst, Division of Plant Pathology (all located at Charlottetown). After examination of the tubers it was evident to these officers that the injury was not due to insects, fungi, or bacteria. Nematodes were observed in the tubers and it was suspected that they might be responsible for the diseased condition of the potatoes. Accordingly, the two latter officers forwarded samples of these tubers to Ottawa for more definite determination of the cause of the trouble. These potatoes were recovered from a farm near York which lies

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about five miles northeast of Charlottetown. The infected stock was Green Mountain and it is reported that, as far as could be ascertained at the time, the trouble was apparently confined to a certain small, low area in one field.

Examination of the nematodes recovered from these Prince Edward Island potatoes revealed that they represented a species of *Ditylenchus* and that they were very evidently responsible for the injury to the tubers. Critical study of the characters of this nematode species showed that they corresponded closely with those described for *Ditylenchus destructor* by Thorne. Furthermore, the characters described by Thorne in his emended description of *Ditylenchus dipsaci* (teasel nematode) did not agree with those observed on the nematodes recovered from the P.E.I. potatoes. However, as Thorne was still giving attention to the taxonomy of the "bulb or stem nematode", and had an expert's knowledge of this problem, specimens were submitted to him for study. Mr. Thorne reported that the nematode found attacking the potato in Prince Edward Island was the potato-rot nematode, *Ditylenchus destructor* Thorne, 1945.

In his article dealing with *Ditylenchus destructor* (4), Thorne states that he compared the characters of this species "with specimens collected from potatoes intercepted by inspectors in ship's stores at the port of Boston in 1932 and found them to be the same". While it is rather probable that these potatoes came from Prince Edward Island, Thorne was careful to refrain from making this statement until more definite evidence had been secured. However, with the recovery of specimens this year we now have clear evidence that the potato-rot nematode is present in a small portion of one field in Prince Edward Island.

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THE DIAGNOSIS OF BACTERIAL BLACK CHAFF OF WHEAT[1]

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INTRODUCTION

Divergent views on varietal resistance to bacterial black chaff of wheat have been held by various investigators and it appears likely that some, at least, of the conflicting statements that have appeared have been due to a failure to distinguish between bacterial black chaff and certain other diseases. For this reason it seems desirable that the means of diagnosing bacterial black chaff be given special attention.

For a good description of bacterial black chaff and an accurate, though limited, description of its causal organism, we are indebted to several investigators who studied the disease shortly after its appearance in severe epidemic form in Kansas in 1915. Although Melchers (18) had begun to study it two years earlier, the 1915 epidemic resulted in increased activity by him and by others in an endeavour to determine the characteristics of the disease. For example, Smith (21) stated that, in the summer of 1917, 14 persons were working under his direction on this problem. Following publication of the description of the disease (20) it soon became apparent that it was widespread in the cereal-growing areas of the world and was capable of occurring in epidemic form whenever conditions favourable to its development were present (5, 6, 8, 12, 19, 24). In Manitoba, it was severe in 1928 (16), and again in 1935.

Some years ago, owing to inadequate diagnoses, dark discolorations of wheat plants were generally attributed to bacterial black chaff. Subsequently, however, when wheats of widely divergent genetic origin were being used as parents in intensive plant breeding programs, it soon became evident that discolorations of the black chaff type were not all of identical origin (9). Some of the discolorations did not appear to be of bacterial origin. In fact, it soon was shown that dark discolorations, which could easily be confused with bacterial black chaff, might occur either alone or associated with that disease (10). Furthermore, it is now known that macroscopically indistinguishable discolorations of more than one origin may be found on a single head of wheat. Consequently, in making field plot estimates of bacterial black chaff severity, it is necessary to use suitable diagnostic methods in arriving at a correct assessment of the intensity of the disease.

Because of the discolorations of mixed origin just referred to, efforts have been directed by the writer toward the development of diagnostic methods that would facilitate the making of determinations from relatively large numbers of lesions. It was hoped that the serological method developed in Russia (2), and mentioned below, might be adaptable for use on the bacteria obtained directly, that is, without pure culturing, from individual lesions of bacterial black chaff. Unfortunately, in the presence of

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plant tissues and juices, this method did not prove reliable. With this as with other methods, it was found necessary first to isolate the organism. The purpose of the present paper is to outline the use of various aids to the diagnosis of bacterial black chaff as practised at this laboratory.

PROCEDURE FOR THE DETECTION OF BACTERIAL BLACK CHAFF

Examination under Low Magnification

To determine whether or not the disease is present, discoloured heads, stems, and leaves of wheat are examined with the aid of a dissecting microscope, or a hand lens, for the presence of bacterial exudate, which may be present either in the form of a thin transparent scale or as yellowish beads. When this examination is made in the laboratory, the heads are illuminated by a strong beam of light, preferably passed through a pale blue or green filter. Such an examination will reveal also the pycnidia of *Septoria* spp. (25), if present, or any dark spore masses of pathogenic or saprophytic fungi. The absence of pycnidia should not be regarded as proof that Septoria glume blotch is not present; neither should, in itself, the presence of spore bodies or masses be accepted as evidence that bacterial black chaff is not present, for saprophytic or weakly parasitic fungi sometimes fructify on tissues parasitized by the bacterial black chaff organism.

In making a visual examination, it should be borne in mind that both microbiological agents and environmental factors may play a part in giving rise to visually similar discolorations. Generally, however, certain symptoms characterize each of the discoloration types. In bacterial black chaff (20), the glume lesions consist typically of dark-brown to black, more or less sunken stripes, occurring chiefly on the upper parts of the glumes, yet heavy infections sometimes have a chocolate-brown appearance, markedly resembling the discolorations caused by *Septoria nodorum* Berk. In Septoria glume blotch (25), the chocolate-brown to black spots often bear punctiform, black pycnidia, especially on the exposed portions of the lemma, but when these are not present further diagnostic study is necessary. In basal glume rot (15), the discoloured areas occur chiefly at the base of the spikelet, or radiate out from the base. In brown necrosis (13, 17), and infections by *Helminthosporium sativum* P. K. & B. (23), the discolorations on the heads are often very similar to those of bacterial black chaff. Discolorations of this type, which occur in nature, should be suspected of being bacterial black chaff until isolation tests have proved negative for the bacterial black chaff organism. In pseudo black chaff (3), the blackening is especially intense and occurs mostly on the apical portions of the glumes. In Alternaria blotch (10, 13), the discolorations are usually more diffuse than in bacterial black chaff and often occur opposite unextruded anthers.

A diagnostic feature that is helpful when classifying the discoloration being studied is the location of the majority of the discoloured areas. Bacterial black chaff, Septoria glume blotch, and brown necrosis occur primarily on the outer glumes and exposed apices of the lemmas, while basal glume rot and Alternaria blotch occur chiefly on the lemmas and, to a lesser degree, on the outer glumes.

One point regarding the symptoms of bacterial black chaff which does not seem to have been mentioned in the literature, is that, in varieties of durum wheat (*Triticum durum* Desf.), the glume discoloration is light brown and diffuse rather than dark brown and sharply delimited as in common wheats (*T. vulgare* Vill. = *T. aestivum* L.).

The kernels are shrivelled and may be darkened irregularly following a severe attack of bacterial black chaff (Figure 1). Black tip, due to infection by the basal glume rot organism, differs from bacterial black chaff discoloration in being confined to the embryo end of the kernel.

Dark discolorations of the rachides and of the upper internodes of the culm occur in brown necrosis as well as in bacterial black chaff. Similar discolorations appear to result from purely physiologic causes (10, 14). When they do, the disorder may be referred to as internodal melanism (10). In bacterial black chaff, internodal discolorations are found only when the attack is severe, but in brown necrosis they appear to be a common feature of the attack. On the other hand, dark discoloration of the peduncles is a common feature of bacterial black chaff, but similar discoloration may also be present in plants affected with Septoria glume blotch, Alternaria blotch, or brown necrosis.

The foliage symptoms of bacterial black chaff are as described by Melchers (18), who mentioned glistening varnish-like areas with lesions denoting bacterial infection. Such semi-translucent areas are characteristically present in the leaf lesions. Histological examination has shown that the translucency is due to the partial dissolution of the mesophyll and the occlusion of all air spaces by bacterial masses. Both weather conditions and varietal differences in the host appear to influence the extent of the translucency. Unfortunately, bacterial infection of the leaves cannot be accepted alone as evidence of the presence of bacterial black chaff. Similar symptoms may be caused by the basal glume rot organism, *Pseudomonas atrofaciens* (McC.) Stev. Several heavy leaf infections, both in spring and winter wheats, have proved, on isolation of the causal organism, to have been caused by *Ps. atrofaciens*.

As a rule, the determination of bacterial black chaff by examination under low magnification, alone, can be relied upon only if bacterial leaf lesions are found in association with the typical head and neck lesions, or if a bacterial exudate is associated with the typical head and neck lesions.

Examination under High Magnification

According to Fröier (6), J. Lindberg, at Svalöf, Sweden, established the intracellular and intercellular nature of the bacterial black chaff disease as long ago as 1918. Bamberg (1), similarly, observed bacteria both in the cells and in the intercellular spaces, and his observations are in agreement with those of the writer.

In the examination of tissues suspected of being infected with bacterial black chaff, an attempt should be made to prepare a bacterial smear. Either positive or negative staining is effective, but the negative staining method described by Burkholder (4) is, perhaps, the most rapid. With this method, the smear is made in Congo Red stain and acidified with acid

alcohol before examination at a magnification of about 900 diameters. Smears thus prepared from leaf or stem lesions of bacterial black chaff always show bacteria in great numbers, the bacteria appearing as white rods on a blue background; in glume lesions, the bacteria are sometimes scarce, although usually numerous (Figure 2).

The presence of bacterial rods in large numbers is not sufficient evidence that the disease is bacterial black chaff. The bacteria may indicate the presence of the basal glume rot organism or of a bacterial saprophyte. In a large percentage of samples, cultural studies also are required.

ISOLATION

For purposes of isolation, a small piece of lesioned tissue, usually from 3 to 10 sq. mm. in area, is dipped momentarily in 70% alcohol, then immersed for a period of $\frac{1}{2}$ to 1 minute in 0.1% mercuric chloride solution. After diffusion in sterile distilled water has been permitted for not less than 5 minutes, the piece is torn apart, aseptically, and 4 dilution plates of beef peptone agar are poured from it. The plates are held for 10 days at 26° C. in an inverted position. Repeated isolation attempts on the same samples have shown that this method is effective on the first attempt in over 90% of the samples of bacterial black chaff.

APPEARANCE OF COLONIES OF *Xanthomonas translucens* (J. J. & R.) DOWSON *emend.* HAGB.

The colonies in the isolation plates are viewed with a hand lens in oblique transmitted light (Figure 3). The well-developed, yellow, surface colonies of the bacterial black chaff organism and of all other special forms of the species, are characterized by minute, interblending, internal striations (22). These striations are present only when the colonies are sown thinly. Godkin (7) stated that they appear in f. sp. *hordei* Hagborg in 12 days, and in f. sp. *undulosa* (S. J. & R.) Hagborg in 9 days, but the writer has found that development of the striations depends less on special form differences than on the distance between colonies. Even in cultures from barley, the striations develop in less than a week if the colonies are widely separated.

On the tenth day of incubation, transfers are made from the isolation plates. These isolates are tested for pathogenicity as soon as they are sufficiently well developed.

TESTS OF PATHOGENICITY

The pathogenicity of each isolate is tested at about 25° C. by the inoculation of from 10 to 15 leaves of wheat, oats, barley, and rye seedlings. For uniformity, the same cereal varieties are used from year to year, viz.: Thatcher wheat, Victory oats, Star barley, and Prolific (Spring) rye. In this inoculation, a nichrome needle is flamed and allowed to cool, then dipped in the inoculum and used to wound the very young primary leaves. After being held at about 25° C. for 7 to 10 days under good light conditions and preferably at a relative humidity of about 75%, the inoculated plants are examined for infection. *Xanthomonas translucens* f. sp. *undulosa*

causes water-soaked areas, which later turn a translucent brown on wheat, barley, and rye; *X. translucens* f. sp. *cerealis* causes similar infections on these hosts and also on oats. However, for practical diagnostic purposes, both of these may be regarded as the bacterial black chaff organism, as under field conditions neither of them appears capable of attacking oats.

The pathogenicity test is quite effective in revealing the bacterial black chaff organism and has the additional advantage that with it *Ps. atrofaciens*, the basal glume rot organism, produces a distinctive reaction. This organism causes the wound margins on all four hosts to turn dark brown to black.

Serological Identification

When the results of diagnoses are required at the earliest possible moment, serological methods are particularly suitable. Certain Russian workers (2, 8) have pointed out the practical advantages to be gained in replacing time-consuming morphological and biochemical methods of identification with a rapid drop-agglutination test. They have found this method reliable in distinguishing the bacterial black chaff organism from other bacteria associated with wheat. In their method, a drop of control serum and also a drop of the specific agglutinating serum are placed on a microscope slide. A mass of the bacteria, the size of a pin head, is transferred to each drop, mixed well, and allowed to remain for a few minutes at room temperatures. With positive results, the specific serum becomes cleared with the appearance of granular, whitish aggregates, and the control serum remains unchanged; but with negative results, both drops retain their homogeneous, greyish appearance.

The writer has confirmed, with numerous isolates, the usefulness of the drop-agglutination method as a rapid test for identifying the bacterial black chaff organism in pure culture. In place of the control serum, he has used a phenolated physiological salt solution with equally satisfactory results (Figure 4). The drop-agglutination method furnishes immediate results and for this reason is especially advantageous in certain cases, but with it, as with the pathogenicity test, isolation is a prerequisite. Both methods are well adapted to the testing of large numbers of isolates, but the drop agglutination test fails to differentiate between the special forms of *X. translucens*. To thus differentiate them is the special merit of the pathogenicity test.

Cultural Identification of the Species

Cultural identification of the species *X. translucens* is done after the non-pathogens or serologically non-reactive isolates have been eliminated. In the writer's experience, all isolates not eliminated by either of the other tests have proved to be true to the remaining determinative characters of this species, described elsewhere (11). Before making the cultural studies, a purity test should be made by the examination of well-separated colonies in dilution plates. If necessary, the organism may be readily re-isolated in pure culture from a seedling leaf infected in the pathogenicity test. The re-isolate also is tested for purity and for pathogenicity or agglutination before being used in the remaining determinative tests.

DISCUSSION

Dark discolorations on the heads and stems of wheat plants often cause concern when they appear either in experimental plots of new wheat varieties or in the commercial wheat crop. As such discolorations may result from several different causes (3, 9, 10, 13, 14, 17) the use of suitable diagnostic methods is prerequisite to the subsequent employment of control measures. Where the attempted control measure consists of breeding for resistance to any of the diseases that cause dark discolorations, diagnostic tests are a necessary supplement to field studies on wheats of hybrid origin.

There has been some confusion in the past in respect to the nomenclature of diseases resembling and including bacterial black chaff. The designation "black chaff" was originally made by Melchers (18) and used by several authors (1, 5, 18, 22, 24) with reference to the bacterial disease caused by the organism now known as *Xanthomonas translucens* f. sp. *undulosa*. Several investigators have used it also to embrace dark discolorations that in the light of more recent studies were probably not bacterial black chaff. In addition, the combination "so-called black chaff" has been used in the literature as if synonymous with brown necrosis (17). It is now believed that, with proper emphasis on careful diagnosis, and with the adoption of the correct distinctive names for the various discoloration diseases—Septoria glume blotch, bacterial black chaff, brown necrosis, Alternaria blotch, pseudo-black chaff, and internodal melanism—confusion can be largely avoided.

It is not always difficult to diagnose bacterial black chaff. Where the symptoms are sufficiently well developed, isolation and identification of the causal organism may be omitted. This is particularly the case with a variety such as Thatcher, which is relatively resistant to brown necrosis and Alternaria blotch. On the other hand, in experimental plots where numerous strains or varieties of wheat are present, discolorations of various kinds are apt to occur. As it would be impractical to determine the cause in every individual lesion, resort may be had to a complete diagnosis on representative sample lesions.

Aside from its use in the detection of bacterial black chaff in breeding plots, an adequate diagnosis can serve a useful purpose as a preliminary step in the selection of control measures for diseases in the commercial crop. Any severe outbreaks of dark discolorations may be tested for the presence of bacterial black chaff. If other causal organisms are involved, the proportion attributable to bacterial black chaff may be assessed in order to determine the advisability of adopting measures to prevent its recurrence.

SUMMARY

Because of the difficulty experienced by many investigators in diagnosing bacterial black chaff of wheat, a procedure of diagnosis that has proved effective is presented. All the essential parts of this procedure can be performed with the aid of equipment ordinarily available in a plant pathological laboratory. The procedure consists of the examination of macroscopic and microscopic portions of the diseased tissues, the isolation of the causal organism, and the identification of it by either a study of its pathogenic or of its serologic reactions, coupled with a study of its morphology and physiologic properties.

ACKNOWLEDGMENTS

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ERRATUM

In the January 1946 issue of *Scientific Agriculture* (Vol. 26, No. 1) amend the formula on page 30 to read:

$$\frac{\text{Sum of all numerical ratings}}{\text{Total number of seedlings} \times \text{maximum rate}} \times 100 = \text{Disease rate}$$

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THE IDENTIFICATION OF NYMPHS OF THE GENUS *MELANOPLUS* OF MANITOBA AND ADJACENT AREAS[1]

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LITERATURE

One of the earliest attempts in North America to study and compare nymphal grasshoppers was made by C. V. Riley (45). The species he described are *Melanoplus atlanis (mexicanus)*, *M. spretus*, and *M. femur-rubrum*. Sixteen years later Howard (30) described for the first time the nymphs of *Schistocerca americana* Drury. The ground colours apparently were found to be quite variable, the dark markings fairly constant. Dampf (13), remarking on Howard's descriptions, maintained that his specimens were in the transitional stage between the solitary and migratory phases and that a description of these phases would have been quite different. Twenty-two years again after Howard's work there appeared good descriptions of immature *M. mexicanus* accompanied by excellent photographs. These were presented by Herrick and Hadley (28). Another attempt at comparative descriptions of nymphs was made by Morse in 1921 (38). In his key he separated *M. atlanis (mexicanus)*, *M. femur-rubrum*, and *M. bivittatus*, and several species of other orthopteran families and subfamilies. The characters used are insufficient for distinguishing each species from the remainder of their groups, but can be used quite successfully in Manitoba to-day for differentiating the species with which he dealt. Carothers (3), although she did not point out characters for identifying particular species, made some general observations worthy of note. It was her experience that familiarity with the adult characters made it possible to place a nymph in the correct genus and often even species. She found that colour and colour pattern could be used with some degree of assurance in Tryxalines and Acridines but that it was unsafe as a guide in identifying the later instars of Oedipodines.

Shortly before the appearance of Carother's paper Norman Criddle had begun the study which, had he lived, would likely by this time have covered all Manitoban species of Acrididae. On file at the Brandon laboratory are careful colour descriptions of over half the nymphal Orthoptera

[1] A study of the nymphal grasshoppers of Manitoba was begun nineteen years ago by the late Norman Criddle but his untimely death in 1933 left the project unfinished. In 1935, shortly after the intensified study of grasshopper ecology in the province had again emphasized the need for a method of identifying immature hoppers, the problem was taken up by the writer, and the information presented herein represents the first step in an attempt to fill that need.

A portion of the work was done during a period of nearly two years at the University of Minnesota. The remainder was carried on in Manitoba, partly at the Dominion Entomological Laboratory, Brandon, and partly at the associated field station at Treesbank.

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CONTENTS

of the province, and in many instances excellent drawings accompany the descriptions. In spite of his untimely death he had succeeded in publishing the most comprehensive papers on immature Orthoptera yet to appear in North America. In his first paper (7) he confirmed the generalizations made by Carothers and described the nymphs of 9 species, 6 of them of the genus *Melanoplus*, but without attempting any great degree of comparison. In his next paper (8) he characterized the Tryxalinae, Oedipodinae, and Acridinae (Cyrtacanthacrinae) and described (with emphasis on the first instar) a number of species in each group, adding 4 more to his previous list of 6 species of *Melanoplus*. Four excellent plates of first instar nymphs are included in the paper. He referred to the reasonable constancy of the colour pattern, especially that of the hind femur, and pointed out the usefulness of the male genitalia in the later instars. Although comparisons are more frequent than in the previous paper there is still a notable lack of them. In a later paper (10) he redescribed the more injurious species of the genus, figured the first and a few fourth instar nymphs, and gave a brief key to the first stage hoppers. Two other papers (9, 11) describe an additional species each.

One of the most intensive pieces of work yet conducted on the morphology of the nymphs of any species was submitted in 1926 to McGill University by R. M. White (61). This unpublished thesis contains a complete and excellent series of detailed drawings of all stages of both sexes of *Camnula pellucida* Scudder. Although the species is not compared with any other, two conclusive statements are of interest to the present study: (1) "*Camnula pellucida* Scudd. varies greatly in different specimens of the same stage of growth"; (2) "In general the nymphal stages are very much like the adult except that the sclerites are not as clearly defined." The colours of the same species had been previously described and the first stage figured by Treherne and Buckell (56).

The occasional occurrence of a sixth nymphal instar in *M. mexicanus* has been mentioned by Parker (41), and Shotwell (47) figured and described this "extra" instar in a paper clearly defining the various stages and the two sexes.

For Europe, Asia, Africa, and South America there is a considerable number of papers, among them Coleman (6), Lebedev (33), Dampf (13), Zolotarevsky (62), Faure (19), and especially Uvarov (57), in which descriptions are given of immature stages of individual species, especially of those exhibiting phases. Little or no attempt at comparison with other species is evident in any of the papers. About the time that Criddle's more extensive papers were published on this continent there appeared a number of publications of a similar nature by Russian workers, Dovnar-Zapolsky (14, 15) and Bey-bienko (1), which the writer was not successful in securing until after the work had been completed.

In his first paper (14) Dovnar-Zapolsky included a key to 9 species, each in a different genus, and to 4 species in the genus *Dociostaurus*. In the second paper (15) his keys, one to earlier and one to later instars, separate 22 genera, but there are no keys to species. He does, however, give fully descriptive keys to separate the different instars of a single species in each of 12 of the genera. In the paper by Bey-bienko there is a key to 24 genera, mostly the same as those listed by Dovnar-Zapolsky (15).

Following this are 12 keys separating 2 species in each of 12 genera, and 3 keys separating 3 species in each of 3 genera. Considerable space is devoted also to biological and ecological observations.

The two authors use practically the same set of characters. Bey-bienko states that, in general, morphological characters are best for separating genera, and colour characters for species, but sometimes the opposite is true. In some groups of species colour is quite useful; in others colour is variable but colour pattern can be relied upon. In still other groups colour pattern, regardless of age or sex, is too variable but ecological factors can be used. In a few instances distribution records are the sole means of differentiating species.

The characters used for separating nymphs of the various genera are those commonly applied to the adults. Thus the slope of the frontal carina and its shape, the ratio of length to width of head, the presence or absence of foviolae and their shape and position, the shape and size of the vertex, shape of antennae, the degree to which the pronotum does or does not extend over the abdomen, the general shape of the pronotum and its carinae and sutures, presence or absence of prosternal tubercle and its shape, and the presence or absence of an arolium, are characters stressed by both writers.

In separating species within a genus, structure is used occasionally but the use of colour and colour pattern is more common. Dovnar-Zapolsky's key to species of *Dociostaurus*, the only one containing as many as 4 species, is fairly representative. Below is a general translation.

1. Occipital ridge present . . . . *D. albicornus*
   Occipital ridge absent . . . . (2)
2. Light stripes of X-pattern of pronotum are of uniform width but are slightly broken in middle . . . . (3)
   Light stripes of X-pattern of pronotum are distinctly broken in middle and each portion extends into light, often white, triangles . . . . *D. kraussi*
3. Genal stripe almost always present . . . . *D. brevicollis*
   Genal stripe almost always absent . . . . *D. maroccanus*

MATERIALS AND METHODS

Sources of Material

A study has been made of representatives of the following 21 species:

Melanoplus angustipennis (Dodge)
Melanoplus bivittatus (Say)
Melanoplus borealis junius (Dodge)
Melanoplus bowditchi canus Hebard
Melanoplus bruneri Scudder
Melanoplus confusus Scudder
Melanoplus dawsoni (Scudder)
Melanoplus differentialis (Thomas)
Melanoplus fasciatus (F. Walker)
Melanoplus femur-rubrum femur-rubrum (DeGeer)
Melanoplus flavidus flavidus Scudder
Melanoplus foedus foedus Scudder
Melanoplus gladstoni (Scudder)
Melanoplus huroni Blatchley
Melanoplus infantilis Scudder

Melanoplus islandicus Blatchley
Melanoplus keeleri luridus (Dodge)
Melanoplus mexicanus mexicanus (Saussure)
Melanoplus occidentalis occidentalis (Thomas)
Melanoplus packardii Scudder
Melanoplus stonei Rehn

All of these occur in the province of Manitoba except *bowditchi canus*, *differentialis* and *occidentalis occidentalis*. *M. differentialis* was obtained from Minnesota and Nebraska and the other two species from Alberta. Except for *borealis borealis*, which Hebard (25) has recorded from Aweme, Manitoba, and which Donald Denning (unpublished) collected in 1937 at Churchill, Manitoba, all species and subspecies occurring in the province are believed to be represented. The Manitoba material was obtained largely from Aweme but large numbers of *mexicanus* and *infantilis* were secured from Lyleton, *bivittatus* from Arnaud, and *femur-rubrum* from Miami. The *stonei* and *bruneri* were all obtained from the Sandilands Forest Reserve east of the Red River. All specimens of *packardii* were from Lyleton. In a few instances the series studied was limited in part or entirely to a small number of specimens preserved 7 to 9 years ago by Norman Criddle. This was true of all instars of *islandicus* and *huroni*, of all except the first instar of *borealis junius*, of the second and fifth instars of *bruneri* and the fifth instar of *infantilis*.

At first no material was used except that obtained from known adults. These were collected in the field and placed in breeding cages until the end of the oviposition period when they were shipped to Mr. Morgan Hebard who very kindly made the final determinations. As the writer became more familiar with the habitats and nymphal characteristics of a species, collections were made directly from the field. In instances where eggs of doubtful identity were secured in the field, a few males were reared to maturity from each pod and these also received the attention of Mr. Hebard.

Condition of Preserved Specimens and Methods of Preserving

Preserved specimens, even those stored as long as 9 years, were often in excellent condition. Others, however, were not entirely satisfactory even though obtained during the past year. It is not easy to preserve specimens at just the right stage. Nymphs that are killed too soon after moulting are apt to be poorly filled out and rather soft; if taken too late the integument of the next stage will have begun to form, a process apparently initiated but little later than half-way through the preceding stadium. A common disadvantage inherent in such specimens is the tendency of the tissues to withdraw slightly from the exoskeleton. This makes photographing rather difficult since the empty, transparent sheath formed by the old integument permits the passage of rays from the back light. Evidence of this will be seen in some of the plates.

Although properly preserved specimens will retain their colour pattern for years, an alteration of the general colouring commonly occurs. Some darken rather quickly, others more slowly, while in some instances an actual fading seems to take place. For this reason, specimens of some species, although satisfactory from the standpoint of markings, show in the plates

as darker or lighter than species which they resemble more closely in life. One notable example of this is Figure 11 in Plate VII. This species *M. occidentalis*, in life is very similar in general appearance to *M. gladstoni*. Reference to Plates III to V shows how dull many of the preserved specimens are when compared with the fresh ones.

Some of the material was preserved in Hood's solution[1], and a very little in one part commercial formalin and 19 parts water, but the bulk of it was stored in 70% alcohol. These solutions were about equally satisfactory but the green colour was not maintained by any of them. It was found that the colour pattern was best preserved by dropping the live hoppers directly into the preservative. When specimens were first killed in hot water much of the contrast between light and dark markings was lost, some species being more affected than others.

In dried nymphs all the markings remain reasonably distinct except those of the eyes. These are always altered to some extent and as a rule are completely destroyed. Moreover much shrivelling of the parts makes examination difficult.

Breeding and Rearing Methods

In breeding and rearing the partly described (7) methods of Norman Criddle were used. Two-quart glass preserve jars, with an inch of slightly moistened soil in the bottoms and wire screening pressed into the tops, served as cages. Whenever possible direct sunlight was used as the main source of heat, raising the temperature commonly to between 90 and 100° F. It was found possible to rear individuals in unlighted temperature cabinets without any apparent abnormality in either colour or structure, but mortality was greater. Mortality was also high during a period when rearing was being done in a greenhouse where a high humidity was maintained.

During the summer months the preferred foods (see Criddle, 12) were used as much as possible for both breeding and rearing. The foods of the more restricted feeders, however, could not be grown conveniently during the winter and other diets were found reasonably satisfactory. Wheat seems to serve quite well as a basic food but it was found desirable to supplement it with dandelion, lettuce, and wandering jew. In some instances too continuous a diet of the last mentioned plant seemed to increase the mortality.

Methods of Study

To make a complete study of all the minute sclerites of all 5 instars of both sexes of all 21 species would obviously require many years of patient and industrious research. Realizing this it was decided to select 2 species on which such a through comparative study could be made, the results to be used as a guide in less intensive examinations of the remaining forms. *M. femur-rubrum* and *M. bivittatus* were selected for this purpose. One reason for the selection was that *femur-rubrum* is the type species of the genus. Another reason lay in the fact that the lighter coloured forms of *femur-rubrum* are very easily confused with the darker forms of *bivittatus*

[1] This solution is made up as follows: 18 oz. 95% commercial ethyl alcohol; 6 oz. distilled water; 2 oz. 7% glycerine; 2 oz. acetic acid; 1 oz. benzol.

and a method of separation based on structure would be a decided advantage. The main reason, however, was that the adults are, for the genus, very different structurally, and if morphological differences were to be found in the nymphs of the genus it was decided that they would surely be discovered in a comparison of these 2 species.

For examination of structural details it was found advantageous to clear the hoppers in potassium hydroxide before dissection and then mount the parts on slides in Canada balsam. Staining, although a definite visual aid in handling the minute sclerites, was found to be of little value otherwise.

Methods of Photographing

The manipulation of specimens for photographing presented a distinct problem in itself. After many unsuccessful attempts to cement pin points in an upright position on various types of glass a satisfactory mount was finally secured, on the suggestion of Dr. R. D. Bird, by forcing the pins through a thick sheet of celluloid. The length of the points and their spacing necessarily varied with the size of the specimen being photographed. One pin was used for impaling the thorax, the next spaced so as to attach the head, a third was set to hold the right leg above the position of the abdomen (as in plates III to VII) and a fourth and longer point to hold the left leg in a corresponding position below the abdomen. A section of a millimeter rule was then cemented to the celluloid on a level with the point of focus to show the exact magnification of each specimen. This saved considerable time and tended to prevent inaccuracy since the different subjects were photographed at different magnifications[1]. To prevent reflection from the integument the specimen was submerged in 70% alcohol in a petri dish. Subjects of different sizes, but for use in the same series, required slight differences in focusing. This was accomplished by placing the submerged specimen on an adjustable opal glass platform by means of which it could be raised or lowered without altering the focal length of the camera, thus leaving the magnification unchanged. All exposures were sufficiently magnified so that the figures presented in the plates could be secured by means of contact prints rather than enlargements.

RECOGNITION OF INSTARS

A study of morphological characters is complicated by changes that occur as the insect develops, hence to use such characters intelligently recognition of the various instars is essential. Dyar (16), working with lepidopterous larvae, used head width for this purpose and his principle was applied to various orders by different workers, Przibram and Megusar (43) finding it satisfactory for determining the stages of the orthopteran, *Sphodromantis bioculata* Burm. Hodge (29) found that the instars of *M. differentialis* were in general indicated by the length of the hind femora but that considerable variation occurred. No doubt the sizes of still other skeletally limited body parts could be used to determine nymphal instars but even if such determinations could be made with perfect accuracy the method would be a very cumbersome one, a separate table being required for nearly every species.

[1] To conserve space only one print of the rule was included with each set of plates of the one series.

Spett (53) was able to determine the 4 instars of *Chorthippus parallelus* Zett. quite satisfactorily by means of the external sex organs, but Else (18) working with *M. differentialis*, found these characters not entirely dependable.

An excellent key to the stages of *M. mexicanus* is given by Shotwell (47). He used wing pads as the major character, with length of third femur and number of antennal segments as next in importance. The general shape of the pronotum, condition of the median carina, shape of the supra-anal plate, appearance of the cerci and podical plates, are all used more or less incidentally. The writer has found this key quite satisfactory except as indicated below for the number of antennal segments.

A method more or less applicable to all species is that used by Riley (45), Carothers (3), Morse (38), Criddle (8) and others. These workers determined the various instars on the basis of the development of the antennae, pronotum and wing pads. The writer has found, as did Else (18), that in the genus *Melanoplus* the antennae and wing pads used together are more dependable than any other structures.

The five instars most commonly present have 13, 17, 20, 22, and 24 antennal segments, respectively. Failure of some of the segments to divide completely not infrequently causes variations to occur in these numbers. It is easy, also, to overlook certain divisions that are actually present but are inconspicuous. Thus, in the early instars especially, the two terminal segments, the last of which is both narrow and short, are frequently counted as one. Counting these as 2 no matter how poorly the division is indicated, and counting the scape and pedicel, the occurrence of less than 13 segments in the first instar was rare in the material studied; 17 segments was the usual number for the second stage with occasionally just 16; 18 to 20 segments occurred in the third; 21 to 22 in the fourth; and 23 to 24 in the fifth instars.

The development of the wing pads in the 5 normal instars is shown for *M. femur-rubrum* in Plate I. In the first instar the pads are scarcely evident, being indicated merely by an almost indiscernible fold. In the next two stages the pads grow downward and backward but often not enough more in the third instar to make it easily distinguishable from the second. Venation, however, is commonly indicated in the former but not the latter. In the fourth instar the wings are turned upward, the tegmina lying underneath those on the metathorax. The latter almost touch each other but only at their tips. In the fifth instar they are more or less horizontal and approximate each other for half of their length.

Thus the first 3 normal instars can be separated from the last 2 by the position and development of the wings and from each other by the number of antennal segments; the last 2 can be determined most safely on the basis of wing development.

In all brachypterous species except one (*M. islandicus*) the wings though usually somewhat shorter than in corresponding stages of long-winged species have the same general form as these latter. *M. islandicus* (Plate I, Figure 6) has extremely abbreviated wings in the adult stage and correspondingly short ones in the immature stages.

Parker (41) and Shotwell (47) have described an "extra" instar as occurring in some individuals of *M. mexicanus* between the normal third

and fourth stages. This Shotwell characterizes as having 19 antennal segments, as being almost as large as the normal fourth instar, and as having wing pads that still point downward as in the third instar but are more elongate, are pointed, and show more distinct venation. It has also been reported by Criddle (12) for *M. bivittatus*, especially females. Although not encountered in the rearing work done during the present study, occasional specimens taken in the field except for the presence of 21 antennal segments definitely answer Shotwell's description. As to the possible cause of the "extra" instar in *M. mexicanus* Parker (41) reports—". . . . it was found that when reared at 22° and 27° C. there were always 6 instars, while at 32° and 37° C. there were only 5 . . . . At alternating temperatures of 32° C. for 8 hours daily and 12° C. for 16 hours daily there were 6 instars, while at 37° C. for 8 hours and at 12° C. for 16 hours there were only 5 instars." In *M. differentialis* the "extra" instar appears to be the rule rather than the exception and Hodge (29) has reported the occurrence of as many as 7 and 8 instars for a very few individuals of this species. Uvarov (57) mentions that in *Dociostaurus kraussi* the females go through one more instar than the males, and in the rearing done at the Brandon laboratory an "extra" instar has been encountered in females of *M. bowditchi canus* but not in males. The writer has not observed this phenomenon in other species but it is quite possible that it does occur. In this paper the "extra" instar is disregarded in the descriptions because of its close resemblance in both colour pattern and structure to the normal third instar. Thus when the terms fourth instar and fifth instar are used they refer to the last two stages even in *M. differentialis*.

Key to Normal Nymphal Instars

1. Wing pads, when evident, pointing downward and backward . . . . (2)
   Wing pads turned upward . . . . (4)
2. Antennae composed of not more than 13 segments; wing pads not apparent; posterior margin of pronotum transverse, often slightly notched medially . . . . *First instar*
   Antennae composed of more than 13 segments; wing pads evident; posterior margin of pronotum rounded, never notched . . . . (3)
3. Antennae composed of not more than 17 segments; wing pads extending but slightly downward and backward, no veins indicated . . . . *Second instar*
   Antennae composed of 18 to 20 segments; wing pads quite evident and showing slight venation . . . . *Third instar*
4. Wing pads short, those of opposite sides touching, or nearly touching, only at tip; antennae with 21 to 22 segments . . . . *Fourth instar*
   Wing pads more elongate, horizontal, those of opposite sides approximating each other on distal half; antennae with 23 to 24 segments . . . . *Fifth instar*

SEX DIFFERENTIATION

Since in this genus the species are differentiated largely on the basis of the genitalia, especially those of the mature male, it is required that one be capable of distinguishing the 2 sexes in all stages. Nelson (40) states that the sexes can be quite readily differentiated in the embryo. Shotwell (47) clearly describes and figures the different developmental stages of the external genitalia of the males and females of *M. mexicanus*. The same structures of *M. bivittatus* and *M. femur-rubrum* are shown in Plate II. The only constant difference in the first instar is the presence in the females of the rudimentary ventral or first valves of the ovipositor. These are evident as 2 minute tubercles on the posterior margin of the eighth sternite.

The upper or third valves are usually separated from the ninth sternite by light sulci and the ninth sternite itself is not as convex as the same sclerite in the male. The difference, however, is very slight and the sulci often indistinct or absent. Under these circumstances the sexes look very much alike, and if the ventral valves are overlooked the females are likely to be mistaken for males. In the second instar the ovipositor valves are all easily distinguished but no other differences are evident. In some species, at least, the cerci are slightly differentiated in the third instar and in a few species the furculae begin to make their appearance at that stage. The ovipositors of the female and subgenital plate of the male are, of course, even more distinct. In the fourth and fifth instars the same structures, as shown by the figures, become increasingly differentiated.

Secondary sex characters have not been studied but no doubt these are present in the species being considered. Spett (53) studied 8 such characters in *Chorthippus parallelus* Zett. These consisted of the head width, width of the pronotum, length of the pronotum, distance between the lateral carinae of the same, length of the right hind femur, length of the right antenna, length of the right tegmen, length of the right wing. Sexual differentiation in these characters appeared gradually with advancing age, being absent in the first instar, absent or nearly so in the second, evident in the third, quite distinct in the fourth (last nymphal) instar and greatest in the adult. Differences in the external sex organs, on the other hand, were clearly indicated in both sexes at the time of hatching, these differences naturally increasing with advancing age. The same author (54) compared *C. parallelus* with *C. albomarginatus* and found that the differences in secondary sex characters exhibited by the 2 species were more an example of sexual dimorphism than of species difference. On the other hand, the more constant species differences that occurred throughout the various instars developed independently of the secondary sex characters.

STRUCTURAL CHARACTERS

The study of structural characters, as pointed out in the preceding sections, is complicated by the existence not only of sexual differences but of developmental differences as well. This is manifested in the group by an increasing similarity in the species as one proceeds from the adults to the first instars, and since the species are delimited largely on the basis of the male genitalia the probable failure of diagnostic morphological characters in the early instars, especially females, could perhaps have been anticipated. The structures discussed are indicated in text Figure 1.

Of the various individual characters, body size and size of body parts, both absolute and relative, were considered impracticable and passed over with little or no study. In the first place, assuming that the individual variation is small enough to make accurate species determination possible, the method would be extremely cumbersome to use where so many instars of both sexes of so many species have to be taken into consideration. Moreover, the use of size is further complicated by the occurrence in some species of the "extra" instars that cannot be properly compared with normal instars of other species. Still further discouraging its use is the fact that in species most nearly alike, a comparison of individuals has shown that although there may be slight differences in mean size, there is considerable

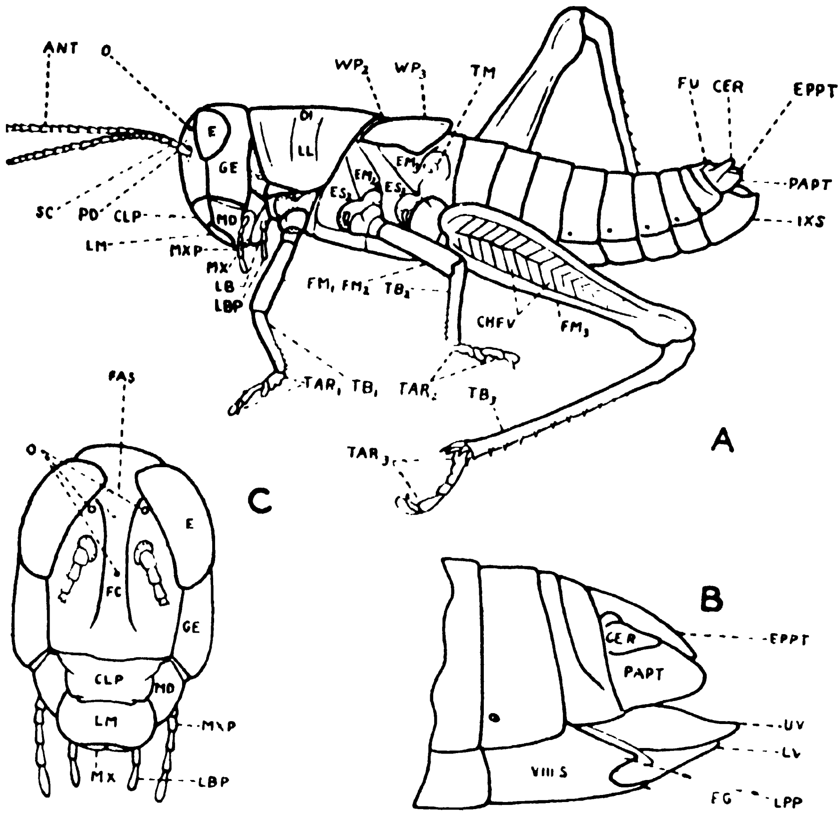

FIGURE 1. A. Lateral view of fourth instar male. B. Lateral view of genitalia of fifth instar female. C. Anterior view of head of third instar female.

ANT,	antenna	CER,	cercus	E,	compound eye
CLP,	clypeus	DI,	disk of pronotum	EPPT,	epiproct
EG,	egg guide	ES,	episternum	FAS,	fastigium
EM,	epimeron	FM,	femur	FU,	furcula
FC,	frontal costa	IXS,	subgenital plate	LB,	labium
GE,	gena	LPP,	latero-posterior projection	LL,	lateral lobe
LBP	labial palpus			LV,	lower valvula
LM,	labrum	PD,	pedicel	MX,	maxilla
MD,	mandible	TB,	tibia	O,	ocelli
MXP,	maxillary palpus	VIII S.	eighth sternite	SC,	scape
PAPT,	paraproct	—1,	prothorax	TM,	tympanum
TAR,	tarsus	—3,	metathorax	WP_2,	wing pad of mesothorax
UV,	upper valvula	CHEV,	chevrons		
WP^3,	wing pad of metathorax overlying wing pad of mesothorax			—2,	mesothorax

overlapping in all stages; and in species where the difference in size is unquestionably significant, other more easily usable characters are sufficiently distinct and constant to make unnecessary the use of such a clumsy characteristic as size. Above all it is felt that anything as variable as body size or size of body parts should be studied over a very large series of individuals of all instars and both sexes, a task quite out of proportion to the obvious degree of usefulness of the results. Thus, for example, the hind femora of some species are undoubtedly longer than those of others, but it is necessary to know the instar before such a character can be used, yet femur length is itself sometimes used as a secondary criterion for stage of development. The same is true of antennal length. The ratio of eye width to the distance separating the eyes at the vertex is of value in separating the adult females of some species; it is, however, of little or no value in males or in early nymphal females.

The shape of the various sclerites, the mouth parts, compound eyes, ocelli, fixed sclerites of the head, hypopharynx, epipharynx, pronotum, mesonotum, metanotum, pleural and ventral thoracic sclerites, legs, wings, spiracles, tympanum, epiproct, paraprocts, furculae, cerci, subgenital plate, ovipositor valves, and eighth sternite, all received attention. It was found that none of these showed specific differences throughout all the instars. The light-coloured mark that occurs at the base of the antennae in adults, and is a valuable aid in separating females of some species, does not appear at all in the nymphs. The prosternal tubercle, though of slight value in the fifth instars of a few species is of no value in any of the other instars; in fact, it cannot be seen in the first two instars and sometimes not even in the third. The posterior margin of the pronotum, characteristically shaped in adults of at least 1 species, *islandicus*, is of little value in nymphs except perhaps in the fifth instar. The distance separating the metasternal lobes, although quite variable, is greater in *huroni* than in any of the other species. This difference is not as great in the nymphs but is apparent to some degree in the fourth and fifth instars. The number of spines on the anterior row of the second femora is commonly greater in some species than in others, but in every species studied a moderate number of individuals carried the same number of spines as the species from which it was desired to distinguish it. The wings were found to be specifically designed only in *islandicus* and even in that species were of no value except in the last two nymphal instars.

The abdominal structures, particularly the genitalia (see Plates IX to XII), showed a little greater promise and deserve more attention. The furculae are particularly useful in some instances. Since they do not occur at all in some species and appear as early as the third instar in others, their mere presence serves for differentiation, and in a few instances they show characteristic size and shape. The fifth instar males of a majority of species can be identified by means of the cerci, for by that time these structures have begun quite noticeably to have taken on the characteristics of their full development. In many of the species they are also helpful in the fourth instar but in very few do they show sufficient differentiation in third stage nymphs. The tip of the male subgenital plate also begins to take on the adult characteristics in the last 2 instars and in those stages is an aid in identifying a few species. The internal male genitalia, used so

advantageously in adult males (Hubbell, 31), are of comparatively little value in the nymphs. In both fresh and well preserved fifth instar nymphs the parts though poorly pigmented are sufficiently sclerotized to show a definite resemblance to the adult. In the fourth instar some individuals of a few species could be separated on that basis but not all of them, and unless material is quite well preserved the parts break down and the distinctive structure destroyed. Even in fresh nymphs it is difficult to expose the internal genitalia without spoiling the specimen.

There are females of several species that have distinct lateral projections on the posterior margin of the eighth sternite (see Plate XII, Figure 18B) while others have none. In most of these the projections are noticeable in the fourth instar, and in 2 species, *bivittatus* and *differentialis*, the degree of development is also characteristic. The shape of the upper valvulae, a valuable character in grouping adult females, can also be used for grouping the fifth instars, but is of doubtful value in the fourth.

It will be seen from the above discussion that *no structural characters have been discovered that can be used satisfactorily for identification of the first 2 instars, that only a few third instar males have structures that can be used as a guide to species, but that most fourth and fifth instar males and some fourth and fifth instar females can be traced to species from a knowledge of the adult structures.* Although this is a disappointingly incomplete state of affairs it is of greater value than would at first appear, for, as pointed out in a later section, a series of specimens taken from one locality usually contains a few specimens more advanced than the others which can thus be more readily identified and in turn can be used, by comparison, as an aid in identifying the earlier instars.

STRUCTURES REQUIRING FURTHER STUDY

There are a number of structures which have not yet received all the attention they may deserve. For instance, in comparing the two species in Plate II, it will be observed that the tips of the subgenital plate are a little more widely separated in *M. femur-rubrum* in proportion to the size of the sclerite, than they are in *M. bivittatus*. This difference appears to be constant and may possibly be of some value in other species in which they have not been studied. Length of antennae, although as already stated a cumbersome and difficult character to use, deserves further study especially in the early instars where identification is difficult. Another structure which should be studied in all species, for identification of mature females if not nymphs, is that which Snodgrass (51) figures for *M. femur-rubrum* and terms the second basivalvular sclerite, and which Walker (59) figures for *M. bivittatus* and refers to as the third basivalvula. In the few specimens in which this sclerite has been studied by the writer, it appears to be constant and fairly diagnostic. The epiproct although quite variable does appear in some instances to show specific differences, but it requires considerably more attention before its degree and manner of usefulness can be stated. The same is true of the chevrons marking the outer surface of the hind femora. The *campaniform sensilla* of the legs, which Pringle (42) has found to occur regularly and in a fairly definite pattern on *Periplaneta americana* L., might prove useful in some species of *Melanoplus* although their practical value would be greatly reduced in any case because

of their microscopic nature. Thus the writer does not claim to have exhausted the complete stock of possible structural diagnostic characters of all the species, but the ones discussed are certainly the most usable.

COLOUR AND COLOUR PATTERN

A consideration of all the factors known to cause variation in the colours and colour patterns of grasshoppers would lead one to conclude without hesitation that the characterization of species on that basis was entirely out of the question. In the first place it has been shown by several authors, Dampf (13), Uvarov (57), Zolotarevsky (62), Tarbinskii (55), and others for migratory locusts, by Rubzov (46) for non-swarming hoppers, and by Faure (20) for *M. mexicanus* of this country, that there are marked colour differences in solitary and migratory phases of the same species. Moreover, according to Rubzov, interwoven with the phase colorations are a number of variations dependent entirely upon the mechanisms of heredity, and King (32) has established the fact that melanism is inherited in *M. differentialis*. Inherited differences in colour pattern occur in the pigmy locusts also (Nabours, Larson, and Hartwig, 39). To further complicate matters it has been shown experimentally by Eisentraut (17), Parker (41), and Faure (19) that differences in environmental conditions can cause distinct differences in colour.

Certainly the majority of species discussed herein show considerable variation in basic colours, green forms being not uncommon even in some of the darkest of them. Which of the three factors, genetic constitution, phasic condition, or immediate environment, brings about these variations is something beyond the scope of this paper, but the fact remains that they do occur. And yet, in spite of these variations, basic colour has its place in that complex of impressions that leads one to recognize the species of nymphal grasshoppers, for, over a period of years in an area the size of a province or state, the great majority of individuals of a given species will be of a more or less characteristic colour.

Colour pattern, as distinct from basic colours, also has its limitations since there is a general tendency for the dark areas to contract or expand with the lighter or darker colour forms of the species. Certain parts of the body do, however, exhibit a definite type of pattern which, once its variability and limitations were firmly fixed in mind, has been found extremely useful in Manitoba. In some species, it is true, the pattern is not as sharply defined in the early instars as it is later, but in the majority of them it holds throughout all stages and in a few it is even more striking in the first instar than in the others. Where colour pattern fails, as it not infrequently does in a few species and more rarely in nearly all species, the early instars cannot be identified with certainty.

The general pattern (i.e., the ratio of dark to light shades, the degree of uniformity or "brokenness" of the dark areas, the degree of contrast as between light and dark shades) is subject to considerable variation but shows some degree of specificity. Considering more limited areas, distinct and reasonably constant differences of colour and pattern have been exhibited by most species in the compound eyes, the genae, the lateral lobes of the pronotum and the hind femora.

The markings on the hind femora are particularly useful and in most species they are remarkably constant, varying but little in individuals and showing the same characteristics in the early as well as the later instars. Dark forms of a few of the species, however, although recognizable with practice, would not be recognized from a description of typical specimens, and the markings on the femora would probably throw the specimen into an entirely different group.

The markings on the compound eyes (see Plates III, IV, V and VIII) are sufficiently specific and sufficiently constant in a few species to enable the identification of all nymphal stages of both sexes without the aid of any other character. Where not specific, there is often sufficient difference that groupings may be accomplished thereby, and in some instances species may be separated that have already been grouped by means of other characters. In several species the markings are subject to considerable variation in individuals, the tendency in general being for the first instar to be less constant than the remaining stages. This character, like others, is dealt with fully in the descriptions of species.

The lateral lobes of the pronotum have markings which, although quite variable, become extremely useful with practice. Except in the very greenest forms of *foedus*, *packardii*, and *angustipennis*, the disk of the pronotum has a slightly shadowy to quite black margin that encroaches a little on the upper part of the lateral lobe. Below this the great majority of species have a decidedly pale, more or less crescent-shaped streak which may or may not be bordered with dark shades again on the lower side. The colour of this crescent, the degree to which it extends caudad or cephalad to the adjacent body parts, the presence or absence of markings below it and the nature of such markings when they exist, are all valuable aids the nature of which can be ascertained by a general study of Plates III to VII.

OTHER AIDS TO IDENTIFICATION

Besides colour and structure there are a number of aids to identification that are worthy of special mention. The first of these is a knowledge of distribution records and habitat. The subject as discussed fully by Criddle (12) needs no further elaboration, but is referred to occasionally in the discussion of the species. Secondly, for early species such as *M. confusus* and late species such as *M. gladstoni*, a knowledge of seasonal life-history is advantageous. Last but not least, the usefulness of a properly assembled reference collection cannot be over-emphasized. Such a collection is not as difficult or laborious to build up as it might at first seem. From a variety of habitats weekly collections are made and the material carefully sorted while it is still fresh. As the season advances later instars are encountered and the males at least can be identified by the resemblance of their structural characters to those of the adult. Using these as a guide to colour pattern the species can then be traced back through the various collections even to the first instar. Collection of adults from the same habitats will help to confirm identifications of the nymphs. The same principle applies to the identification of a single collection, for one rarely makes a collection that does not contain a few older individuals of most species and these, being more easily identified, are a useful aid in distinguishing the younger nymphs.

INTRODUCTION

DISCUSSION OF SPECIES

Carothers (3) states that a knowledge of adult grasshoppers will enable one to place an immature specimen in the correct genus and often even species. This statement appears to be largely true, but the use of adult characters in the placement of nymphs of the genus *Melanoplus* is, as already pointed out, limited mostly to the last 1 or 2 instars except in a few species having the general markings of their parents.

Describing the adults of *Melanoplus* and related genera there is a vast literature a discussion of which is beyond the scope of this paper. A knowledge of the fundamental structures can be obtained from many sources, more especially Chopard (4), Walker (59, 60), MacGillivray (34), and Snodgrass (48, 49, 50, 51, 52). Most of the more recent descriptions of species of *Melanoplus* and decisions regarding their synonymy have been made by Mr. Morgan Hebard a very few of whose publications are listed among the references. The work of Blatchley (2) is rather incomplete and out of date as regards synonymy, but it is still a most useful publication, especially for its characterization of the larger groups. Claasson (5) also gives detailed descriptions of *Melanoplus* and the closely related genera. Two papers by Hebard (24, 26) contain concise and very useful keys to many species including all of the *Melanopli* occurring in Manitoba.

The following key, taken from Morse (38), will give a clue as to how the characteristics of the adult may be utilized for separating nymphs of the larger groups:

"A. Antennae ("feelers" on the head) very slender and tapering to a fine point (usually much longer than the body).

B. Colour black or dark brown. Body a little depressed (flattened from above downward). Feet (tarsi—last segment of leg) three-jointed......Field crickets

C. First joint of hind tarsi with stiff spines above. Large Black Field-cricket, *Gryllus assimilis*

CC. Without such spines.................................Striped Grass-cricket Small Brown Field-cricket, *Nemobius fasciatus*

BB. Colour pale green, usually with a dark stripe along middle of back. Feet four-jointed. Green, Long-horned or Meadow-grasshoppers.

AA. Antennae shorter than the body, thread-like but not tapering to a fine point. Feet three-jointed...............Common Grasshoppers (short-horned).

D. Face in side view strongly retreating, making a sharp angle with the top of the head (vertex). Collar (pronotum) nearly flat above, its upper surface (disk) meeting the side at an angle marked by a slight ridge (lateral carina). Slant-faced Grasshoppers

DD. Face in side view rounding smoothly into the top of the head without marked angle at the vertex.

F. Top of collar (disk of pronotum) sloping downward roof-wise, from a median ridge to the low lateral ridges, which diverge strongly backward. Distance between eyes on top of head equalling width of an eye. A robust brown or gray species, mottled with darker, and usually showing a blackish bar across the face on a level with and covering the lower half of the eyes. No prominent projection on the throat between the bases of the front legs in any stage. Clear-winged Grasshopper, *Camnula pellucida*.

FF. Top of collar (disk of pronotum) curving smoothly downward from the low median ridge into the sides; lateral ridges present only in the adult. Distance between the eyes on top of head much less than width of an eye. In the fifth, fourth, and often in the third stages a prominent spine is noticeable projecting downward between the bases of the front legs (prosternal spine). This cannot usually be made out satisfactorily in the first, second, and often in the third stages..........................Spine-throated Grasshoppers."

Morse also describes *M. atlanis (mexicanus)*, *M. bivittatus* and *M. femur-rubrum* and there is a ray of hope in the fact that the characters as

used by him in Maine are useful to-day in Manitoba. But it is realized that, for colour characters especially, those used successfully in one region will not necessarily suffice for the same species elsewhere, nor is it at all likely that the characters used will separate all Manitoba species from all other species of the genus.

In the characterization of the individual species in a later section, detailed colour descriptions are not given for a number of reasons. In the first place the nature of the markings can be gathered much better by reference to the plates, and it is therefore unnecessary to increase the wording and confuse the issue by including cumbersome descriptions. Secondly, and of more importance, the details of the actual colour shades are, as already explained, comparatively unreliable.

No attempt has been made in either the key, the comparative discussion or the plates, to arrange the species according to a "natural" system. Instead, every effort has been directed towards making a comparison of those species which superficially or otherwise resemble each other most nearly and as a result are most easily confused.

Key to Nymphs

The following key is useful as a guide only. In few instances will it separate all individuals of the species listed even when used by one who knows the group reasonably well, and for anyone who has not had an opportunity to make a comparison of a given character in different species it is quite easy to choose the wrong member of a couplet. It is common experience that even the best of keys on the most clearly differentiated material often lead to difficulties in the hands of those unfamiliar with the particular group, and in material as poorly defined as the immature stages of *Melanoplus* the difficulties multiply. For this reason the reader is advised to use the comparisons in the next section rather than the key, at least until he is reasonably familiar with the group. Similarly, it would be unwise to rely on the figures in the plates without first reading the text under "Comparisons of Species".

1. Outer face[1] of hind femur fuscous, broken or not by contrasting light marks, but these when present never cutting completely across fuscous area.....Group I (2)
   Outer face of hind femur either uniformly pale with minute dark spots, or fuscous with 1 or more light bands cutting completely across dark areas.......Group II (11)

Group I

2. Lighter maculations of compound eye sparse, their total area occupying less than one-third of total area of eye..(3)
   Lighter maculations of compound eye numerous, their total area occupying more than one-third of total area of eye..(4)
3. Compound eye with 2 distinct transverse light streaks......*M. keeleri luridus* (Dodge)
   Compound eye with scattered light spots but not transverse streaks *M. dawsoni* (Scud.)
4. Fuscous streak of hind femur not interrupted along either upper or lower margin (see couplet 17 for first and some second instar *M. differentialis*)............(5)
   Fuscous streak of hind femur commonly broken by 1 or 2 pale notches on upper half (7)
5. Compound eye brown to pale brown with small rounded lighter spots uniformly distributed over surface; dark streak on outer face of hind femur confined to upper row of chevrons and upper tips of lower row of chevrons; dark streak on inner face of hind femur rarely broken by transverse lighter band; upper flange of hind femur rarely with dark markings; pronotal crescent present but not always

[1] The outer face of the hind femur refers only to that part marked by chevrons and does not include the flanges.

whitish and if whitish the lighter shade not extending across gena; furculae not present except as minute tubercles in some fifth instar males; fourth and fifth instar females with latero-posterior projections on eighth sternite.
M. bivittatus (Say)

Compound eye brown to fuscous with lighter markings not uniformly distributed (sometimes so in first instar), banding being common; dark streak on outer face of hind femur covering upper and at least one-third of lower row of chevrons; other characters as above or not.......................................(6)

6. Dark streak on inner face of hind femur continuous; markings contrasting greatly; dark areas extensive and uniform; pronotal crescent almost white and connected with area of similar colour on gena; furculae indicated in males as early as third instar; females without latero-posterior projections on eighth sternite.
M. femur-rubrum femur-rubrum (DeG.)

Dark streak on inner face of hind femur interrupted by transverse light band or bands; markings only moderately contrasting; dark areas commonly mottled; pronotal crescent sometimes present but confined to small area; gena yellowish, faintly mottled with brown; furculae never present; fourth and fifth instar females with latero-posterior projections on eighth sternite.....*M. differentialis* (Thom.)

7. Dominant colour gray or green; fuscous markings few but clearly defined; lower half of compound eye never darker than upper half, the darker markings commonly forming transverse zigzag lines; furculae broad and blunt in third to fifth instar males...(8)

Dominant colour fuscous or brown; lower half of compound eye darker than upper half or not, the darker markings never zigzag; furculae either narrow and pointed or else lacking...(9)

8. Dominant colour gray; feeding restricted to *Artemisia cana* Pursh. and possibly closely related species (see couplet 13 for majority of specimens)
M. bowditchi canus Hebard

Dominant colour green; feeding not restricted to one host, rarely or not at all on *Artemisia*..................................*M. flavidus flavidus* Scud.

9. Lower half of compound eye distinctly darker than upper half; pronotal crescent almost white and connected with area of similar colour on gena; entire dorsal area pale cream colour and separated sharply from dark lateral areas............(10)

Lower half of compound eye not distinctly darker than upper half; pronotal crescent usually indicated by a small white spot; gena yellowish with brown spots; dorsal area, if pale, not separated sharply from lateral areas (see couplet 17 for majority of specimens)............................*M. mexicanus mexicanus* (Sauss.)
M. bruneri Scud.

10. Tarsi and tibiae pale; dorsal area pale with few or no brown spots; lateral lobe of pronotum below crescent commonly ferruginous with few or no fuscous spots; darker area on posterio-ventral part of gena narrower than lighter area above it
M. islandicus Blatch.

Tarsi and tibiae (at least distal third) fuscous or nearly so; dorsal area pale but dotted with fuscous; lateral lobe of pronotum below crescent spotted with fuscous; darker area on posterio-ventral part of gena as wide as lighter area above it
M. borealis junius (Dodge)

Group II

11. Crescent absent from pronotal lobe; gena and pronotal lobe darkly marked with mottled brown and fuscous, commonly more so than dorsal areas of head and pronotum
Subgroup A.—*M. huroni* Blatch.

Crescent present on pronotal lobe or, if absent or poorly indicated, gena and pronotal lobe with few or no dark markings, at least fewer than dorsal areas.
Subgroups B and C (12)

12. Pronotal crescent absent; brown and fuscous markings when present commonly in the form of small dots; dots on the pronotum, at least, more abundant on dorsal than lateral areas; green, fawn, or gray forms (with few or no dark markings) often predominating...Subgroup B (13)

Pronotal crescent present but sometimes restricted to small white spot; brown and fuscous markings usually present in larger or smaller patches, and pronotal lobe almost if not quite as dark as disk of pronotum; mostly brown forms, but occasional fawn or green forms never without fuscous patches......Subgroup C (17)

13. Dominant colour gray; feeding commonly restricted to *Artemisia cana* Pursh. and possibly closely related species; furculae broad and blunt in third to fifth instar males (see couplet 8 for a small percentage of specimens)
M. bowditchi canus Hebard

Dominant colour green, fawn, or brown; general feeders, *Artemisia* species rarely attacked; furculae either narrow and pointed or else lacking................(14)

14. Restricted in Manitoba to sandy soil of jack pine areas in northern and eastern sections of the province.................................*M. stonei* Rehn

Not restricted to such areas..(15)

15. Occurring rarely in Manitoba except in 2 limited areas: (1) Area bounded by lines through villages of Gretna, Plum Coulee, Jordan, Miami and Haskett. (2) Corner of province southwest of Deloraine, Lauder, Pipestone and Sinclair
M. packardii Scud.

Occurring generally over province..(16)

16. Dominant colours light brown or fawn; subgenital plate notched or emarginate at tip in fifth instar males and notched or truncate in fourth instar males
M. angustipennis (Dodge)

Dominant colours fawn or green; subgenital plate rounded at tip in fifth instar males, sometimes rounded in fourth instar males but truncate in many specimens
M. foedus foedus Scud.

17. Lower half of compound eye not distinctly darker than upper half, a dark transverse band often faintly indicated at middle of eye; white crescent frequently restricted to a small spot at centre of pronotal lobe; gena usually yellowish and lightly flecked with brown to light brown; tip of subgenital plate notched or emarginate in fourth and fifth instar males........................*M. mexicanus mexicanus* (Sauss.)
M. bruneri Scud.
First and some second instar *M. differentialis* (Thom.)

Lower half of compound eye distinctly darker than upper half, a dark transverse band usually strongly indicated at middle of eye; tip of subgenital plate entire in fourth and fifth instar males...(18)

18. Pronotal crescent and gena with few or no minute spots of brown or fuscous; fuscous patches on outer face of hind femur confined to upper half, lower margins of patches even and in straight line; species with large areas of pale cream and with smaller areas of strongly contrasting fuscous..............................(19)

Pronotal crescent and gena with scattered brown and fuscous dots; fuscous patches on outer face of hind femur encroaching on lower half, lower margins of patches uneven; species with very few pale areas, and these with many fuscous dots...(21)

19. Ventro-posterior area of gena uniformly dusky, the dusky portion as wide as cream coloured streak above and in front of it; lateral lobe of pronotum below crescent uniformly dusky; cerci of fourth and fifth instar males much narrower on distal third than middle third; species not occurring in Manitoba
M. occidentalis occidentalis (Thom.)

Ventro-posterior area of gena same colour (cream) as central area or, if dusky, the dusky portion narrower than cream coloured streak above and in front of it; lateral lobe of pronotum concolourous except for small fuscous spot adjacent to crescent; cerci of fourth and fifth instar males no narrower at widest part of distal third than at middle..(20)

20. Frontal costa much darker than surrounding areas, especially at ventral end (Plate VIII, fig. 22); cerci of fourth and fifth instar males wider at some portion of distal third than at middle; tip of cerci notched or forked in fifth instar males at least
M. infantilis Scud.

Frontal costa but little darker than surrounding areas (Plate VIII, fig. 23); cerci of fourth and fifth instar males no wider on distal third than at middle; tip of cerci never notched or forked.................................*M. gladstoni* (Scud.)

21. Fuscous areas on outer face of hind femur contrasting strongly with the V-shaped cream coloured area cutting across them; transverse bar on compound eye not strongly indicated; cerci of fourth and fifth instar males straight or curved very slightly downward at tip; collected most frequently in bear-berry on sandy soil near conifers; rarely maturing before July 1..........*M. fasciatus* (F. Walk.)

Fuscous areas on outer face of hind femur not solidly coloured; transverse light area diagonal rather than V-shaped; transverse bar on compound eye strongly indicated; cerci of fourth and fifth instar males turned upward and often inward at tip; distributed widely in a variety of habitats; commonly maturing by June 20
M. confusus Scud.

COMPARISON OF SPECIES

GROUP I

Melanoplus keeleri luridus (Dodge)

M. luridus is a contrastingly black and gray species. No green or other striking variations in colour have been observed. It can be distinguished from all of the 21 species by the 2 median light bands running across the black of the eye (Plate VIII, Figure 2). The light spots occurring on other parts of the eye increase somewhat in the later instars but are always few in number. The broad expanse of gray on the pronotal lobe and gena is quite helpful. The narrowing of the femoral stripe proximally is characteristic of all stages including the adult.

Melanoplus dawsoni (Scud.)

This glossy species is likewise one with very contrasting colours, the lighter shades in fresh specimens being pale cream to yellow. The contrast is maintained throughout but is partly masked in the later stages by a grayish cast somewhat resembling, in appearance only, the "bloom" that occurs on plums and other kinds of fruit. The dark pigment of the eye, with or without a few scattered light spots (Plate VIII, Figure 1), serves as in *luridus* to separate all stages from those of the remaining species. The highly polished nature of the exoskeleton also sets it aside from the rest of the group. The black of the posterior femur is frequently broken in the later instars by a light wedge-shaped mark on the distal half of the upper margin.

Melanoplus femur-rubrum femur-rubrum (DeG.)

M. femur-rubrum in its more typical and abundant form is another species with strongly contrasting black and whitish green or yellowish markings, looking not unlike *dawsoni* in general appearance. The characters already given for that species make them easily separable. The darker forms of *bivittatus* can also be confused with *femur-rubrum*, and the green forms that occur in both species are distinguishable only with care. In *femur-rubrum* as much of the area of the eye is covered with light spots as with dark pigment. There is, however, a strong tendency to banding, the lower half being noticeably darker than the upper part. This usually separates the species quite readily from *bivittatus* except in many first and some second instar individuals where the segregation of light and dark pigments is not as noticeable, making those of *femur-rubrum* very similar to the uniformly spotted, brownish eyes of *bivittatus*. The whitish crescent of the pronotal lobe is always present in the first and second instars at least, and continues part way across the gena; in *bivittatus* the crescent is less pronounced and does not reach the head at all. The black band of the posterior femur is not broken in either species, but whereas in *bivittatus* it barely touches the lower row of chevrons, and close examination shows it to be somewhat irregular along its lower margin, in *femur-rubrum* it covers the upper third of the lower chevrons and has an even ventral margin. In the first instars of the latter species the whole outer face of the femur is commonly black or smoky and 2 dusky spots usually occur on the inside of the upper flange if not on the outside; in *bivittatus* the dark pigment fails to cover the lower chevrons of the proximal two-thirds of the femur, appears very rarely on the upper flange, and still more frequently shows only as a narrow streak as in Plate III, Figure 3.

Separation of the last 2 or 3 instars of the species on a structural basis is a comparatively simple task. The furculae appear in third instar males of *femur-rubrum* and are absent in *bivittatus* except as to 2 minute points in some fifth instar individuals. The male cerci and subgenital plates are distinctly different in at least the last 2 instars (see Plates X and XI). In the fourth and fifth instar females, the presence in *bivittatus* and absence in *femur-rubrum* of the latero-posterior projections on the eighth sternite (Plate II) is quite distinctive.

Melanoplus bivittatus (Say)

M. bivittatus is almost completely described by the above comparison with *femur-rubrum*. The species usually has a quite evident yellowish ground colour which may vary from orange to bright green, the green forms seeming to be more frequent, if not predominant, in years of low population. Except in the greener individuals, the dark markings are generously sprinkled over the body in broken and mottled patches. One outstanding characteristic which serves with practice to separate *bivittatus* from the remainder of the group is the uniform distribution of small rounded light spots on the brown basal colour of the eye. The spots may be either distinctly separated or close enough so as to anastomose but they are always uniformly distributed. The comparison below with *differentialis* completes the characterization of this common pest.

Melanoplus differentialis (Thom.)

The general yellowish-orange ground colour that is common in *differentialis* is similar to, although slightly deeper than, that of *bivittatus*. The dark markings, too, are broken up much the same as in the latter species and perhaps even a little more so. Interestingly enough, the close resemblance so evident in the later stages does not exist in first instar specimens which cannot be satisfactorily distinguished from some forms of *mexicanus*. If the individuals figured in Plate IV, Figures 7 and 8, are compared, it will be observed that there is a greater contrast in some of the lighter and darker markings. This, however, happens to be quite unreliable as a general means of separation. Neither can the antennal differences nor any other differences that are observable in the two figures be relied upon, with the possible exception of one. This is the basal streak of the hind femur, and even it has definite limitations. In *differentialis* the streak is relatively heavier than in *mexicanus* and its margins are more nearly entire. There is a tendency, too, in the former species, for the streak to be continued across the lighter area distad to it. This also tends to occur in the darker forms of *mexicanus*, but in these same individuals, as shown in Figure 6 of Plate IV, the dark pigment fills in below the basal streak, a condition not common to *differentialis* unless perhaps in melanistic forms which the writer has not encountered. In the later stages, characteristically as in Plate VI, Figure 5, the black femoral stripe is not infrequently weakened at a point a little beyond the middle, but in the material studied this lighter area rarely causes a complete interruption. In any event the later stages can usually be separated from *bivittatus* by a combination of characters: in *differentialis* the spots on the eye are not uniformly distributed, the white crescent is either absent or very obscure, the femoral stripe covers

at least a third of the lower row of chevrons, there are two dark marks on the upper flange of the same member, and these form two dark bars across the femur on the inside, *bivittatus* commonly differing in all these respects.

The last 2 instars can be separated on structural characters. The best of these are the male cerci shown in Plate XI, Figures 13A-D and 14A-D. In the fourth and fifth instar[1] females the latero-posterior projections of *differentialis* are as long as the egg-guide while in *bivittatus* they are approximately half as long as that structure. (Compare Figure 18B of Plate XII with Figure 5B of Plate II).

Melanoplus flavidus flavidus Scud.

The general colouring of *flavidus* is quite distinctive when specimens are fresh, but of doubtful value in preserved material. The early stages are pale green to cream and the later stages commonly bright green, the green being present in several shades. Dark markings are few but sharply defined. The black stripe on the hind femur is quite narrow, especially towards the ends, and usually has 1 or 2 emarginations on the upper side. Lighter markings predominate on the eye, the darker lines having a more or less zigzag form, and, if any difference exists at all, there is more dark pigment in the upper than the lower half. The variegated green, the emarginations and narrowness of the femoral stripe, and the nature of the eye, all serve to separate this species from the green forms of *bivittatus* and *femur-rubrum* which it resembles considerably.

The furculae can be seen in the third instar as 2 slight but broad swellings. In the fourth and fifth instars (Plate IX, Figures 4C and 4D) they are quite distinctive, *bowditchi canus* being the only species having very similar structures. The cerci of the males differ considerably from *bivittatus* but only slightly from *femur-rubrum*. The subgenital plate differs more from the latter species. The third valvulae of the female are of the *angustipennis* type, those of the other 2 species resembling *differentialis* (Plate XII, Figures 18 and 19).

Melanoplus borealis junius (Dodge)

In *borealis junius* the ground colour varies considerably from pale cream to light brown. Dark brown or black pigment is present in large patches and is scattered over the remaining areas in numerous small dots. The dorsal area is commonly light coloured and sharply delimited from the sides. In the first instar the black pigment covers nearly the whole specimen except the back (Plate III, Figure 6). The femoral stripe covers the greater portion of the outer face of the femur but is broken in 1 or 2 places on the upper half. The eye contains light spots over its entire area but the lower half is considerably darker than the upper half (Plate VIII, Figure 8). The white crescent stands out in sharp contrast to the other markings. The species resembles *femur-rubrum* in some degree but they can be separated by means of the broad dorsal stripe, the greater degree of spotting, the light mark on the femoral stripe, and the stronger differentiation of the eye. The resemblance to *islandicus* is even greater. The differences are listed under that species.

The genital structure of both male and female nymphs are not strikingly different from those of *femur-rubrum*.

[1] These are in reality the fifth and sixth instars of this species, but since they correspond more closely in arrangement of the wing pads and apparently in general maturity to the fourth and fifth instars of the remaining species, they are so numbered for the sake of uniformity.

Melanoplus islandicus Blatch.[1]

M. islandicus very closely resembles *borealis junius* in the major characteristics of colour pattern including the dorsal stripe, femoral stripe, pronotal crescent, and eye marking. It is, however, lighter coloured with very few of the minute black spots so characteristic of the latter species. There is very little dark pigment below the crescent and that which is present is more tan than brown. Tan commonly borders the dorsal side of the crescent also but gives way to dark brown or black dorsally. The pale dorsal area is sharply differentiated from the lateral. Tan also forms a portion of the darker pigment on the abdomen. The femoral stripe and the eye markings do not safely separate the 2 species, but the former narrows more strongly in *islandicus* on the proximal upper margin, and the eye markings are more strongly contrasting and have a greater tendency to form a bar. As may be ascertained from the plates, the pale area of the gena is distinctly wider in *islandicus*, and the tibia and tarsus are pale in that species and dark in *borealis junius*.

The female structures are of the *femur-rubrum* type but otherwise not particularly distinctive. Neither are the fourth instar male structures of special value. No fifth instar males were secured for study.

The species is restricted in Manitoba to thin stands of jack pine, especially if blueberry and bearberry are also present.

Group IIA

Melanoplus huroni Blatch.

The few specimens studied of this rather large, clumsy, dark brown to dark gray species are quite distinctive. The sides of the head and pronotal lobes are quite darkly pigmented, commonly more so than the dorsal areas of the same body parts. There is no evidence of a pronotal crescent or spot. The lower part of the eye is much darker than the upper part. This combination of markings, or absence of markings, differentiates this species from all the others studied.

Except for the first, second, and a single fourth instar, male nymphs were not available for study. The female genitalia were found to be of the *femur-rubrum* type.

The species is rare in Manitoba, occurring in the same type of habitat as *islandicus*.

Group IIB

The species in this group are not clearly differentiated, especially in the early instars, and the fawn and green forms occurring so frequently in *angustipennis*, *foedus*, and *packardii* are practically indistinguishable.

Melanoplus bowditchi canus Hebard

The individuals of *bowditchi canus* used in this study were progeny of adults obtained from Alberta. The fact that these are not being compared with Alberta forms of the other species should be borne in mind. The more common type of individual has a general grayish cast that in itself tends to distinguish it from the other 21 species discussed, but there are variations from this especially in the first instar. Dark markings are usually few except for the scattering of small spots over most areas of the

[1] This was formerly a subspecies of *mancus* but was given species rank by Hebard (27).

body. In some individuals they are a little larger and more distinct, approaching in a moderate degree the markings of *flavidus*. The markings of the eye are also very similar to those of *flavidus* but average slightly darker in the specimens on hand. The markings on the outer face of the hind femur are never as dark as they are on that species and most frequently are quite pale, or else show the transverse lighter band common to darker members of the rest of Group IIB. The stripe on the inside of the femur, however, is dark, and though in a few of the older nymphs there is a suggestion of a transverse light band, the dark stripe is never distinctly broken as it is in the other four species (Plates III to VII). There is no white crescent on the pronotal lobe but a brightening of this area, again somewhat as in *flavidus*, is characteristic. Except for the somewhat greater contrast in markings and the stripe on the inside of the hind femur, there are many individuals especially in the first instar that cannot be distinguished with certainty from some forms of the other 4 species.

Structurally, as would be expected, *bowditchi canus* resembles *flavidus* closely and therefore the males differ considerably from the rest of the group, more especially in the nature of the furculae. These are, if anything, slightly wider than those of *flavidus*. There are no latero-posterior projections on the eighth sternite of the females of *bowditchi* canus but these are present in the other species of Group IIB.

The writer has not seen this species in its habitat but it is reported by Criddle (12) to feed entirely on *Artemisia cana* Pursh. This is probably true in nature, but contrary to Criddle's findings it was reared on wheat, dandelion, and wandering jew, at the University of Minnesota, and adults were induced to produce quantities of fertile eggs when they were fed only on *A. ludoviciana* Nutt.

Melanoplus angustipennis (Dodge)

M. angustipennis is characterized fairly completely by the description of the group. It is an extremely variable species. Pale fawn and green specimens, with a scattering of minute dark spots or with no trace at all of dark markings, are common. However, forms somewhat darker than *foedus* and *packardii* are the rule. In these the dorsum is more contrastingly dark, the sides of the pronotal lobes are more heavily spotted, and the outer face of the posterior femur more strongly barred. But these characteristics do not separate *angustipennis* from *stonei* nor do they differentiate it sharply from some forms of the other 2 species. The slight indication of a small whitish spot on the pronotal lobe, in the usual position of the white crescent, makes separation from *mexicanus* also rather difficult. It can usually be accomplished, however, by taking into consideration the greater tendency to spottiness of the lateral lobe of the pronotum in *angustipennis* and the greater contrast between this area and the darker pronotal disc.

The female genitalia (Plate XII, Figures 19A and B) are not differentiated from any of the remaining members of the group, but those of the fifth instar, and sometimes the fourth, exhibit the latero-posterior projections not present in *bowditchi canus*. The cerci are narrower than in the remaining 3 species but the difference is too slight to be of much value. The emargination at the tip of the subgenital plate separates fifth instar males from the other species but is of only moderate use in the fourth instar.

Melanoplus stonei Rehn[1]

M. stonei averages darker than the other species with slightly more contrast between the lighter and darker shades. Otherwise there is no specific pattern that differentiates it from the darker forms of *angustipennis*. Light forms occur but the series on hand is not large enough to permit an estimation as to the probable percentage. Specimens without some quantity of dark pigment have not been observed.

Fifth instar males have not been examined but judging from the adults it is not likely that there would be any constant structural difference between *stonei* and the next two species.

This is not a common species in Manitoba and up to the present time has been obtained only in pine woods associated with *huroni* and *islandicus*.

Melanoplus foedus foedus Scud.

Light green appears to be the dominant colour form in *foedus*, but fawn individuals, with or without the scattering of minute dark spots, are frequent. Specimens with a darker cast to the dorsum and a definite dark pattern on the posterior femur are also numerous. Any differences which might serve in some degree to separate *foedus* from the other 4 species are mentioned in the discussion of those species.

Melanoplus packardii Scud.

Green and fawn forms seem to be dominant in this species also. In general there appears to be a denser sprinkling of minute round spots of dark pigment, but otherwise the general appearance is as in *foedus*. In all the specimens examined the eye showed little or no tendency to barring but there were 3 or 4 shades of pigment rather than the usual 2. If this proved to be a constant characteristic it would serve to distinguish the majority of individuals of *packardii* from the rest of the group. However, the close resemblance of this species to the others has made field material altogether too unreliable, and it is felt that a large series of reared individuals should be examined before a definite statement about this eye character can be made.

Although *angustipennis*, *foëdus*, and *packardii* occur in cultivated areas of light soil, *packardii* does not appear to be as widely distributed in Manitoba as are the other two species. Rehn and Hebard (44) and Hebard (22) have reported it as occurring at Aweme, Manitoba, but this was before the appearance of Hubbell's (31) paper on the internal genitalia of the males. In a later publication Hebard (23) corrects conflicting reports of *foedus* and *packardii* in Montana. *M. foedus* is mentioned in this paper as occurring at Aweme, Manitoba, but the distribution of *packardii* in the province is not given. From the material in the Brandon laboratory it would appear that *packardii* occurs but rarely in Manitoba except in a small area in the corner of the province southwest of the towns of Deloraine, Lauder, Pipestone, and Sinclair, and in another small area bounded by lines joining Gretna, Plum Coulee, Jordan, Miami, and Haskett. In both these areas the lightest soil was most favoured.

[1] The only fourth instar male available (Plate VII, Figure 2) was considerably paler than the other specimens on hand, and the difference in contrast of the first instar (Plate V, Figure 2) is due less to the specimen than to the fact that it was taken on a more contrasting film which unfortunately could not be secured again after the original supply was exhausted.

Group IIC

Five of the 7 species included here answer the group description quite closely. The other two, *mexicanus* and *bruneri*, are extremely variable. As in some of the other groups the first instar specimens are often very difficult to separate.

Melanoplus mexicanus mexicanus (Sauss.)

The nymphs of *mexicanus* are extremely variable. The ground colour may be cream, yellowish-orange, or green, or the dark brown pigment may be so extensive as to block out the ground colour almost entirely. Dark markings are present even in the green specimens. The femoral stripe is commonly broken by a light band as in Plate IV, Figure 7, and Plate VII, Figure 12, but in the darker individuals the transverse band is limited to a pale spot as in Plate IV, Figure 6. Thus the dark individuals would find their way into Group I, but they can be separated from the members of that group by the reduction of the pronotal crescent to a mere spot in *mexicanus* and by the more distinctive eye characters of the other species. In *mexicanus* the eye is weakly barred in most specimens, with very little difference in degree of pigmentation above and below the bar. The white pronotal spot common to most dark individuals becomes a whitish crescent in the lighter forms. This frequently appears to encroach on the gena but this latter area usually is spotted lightly with brown, or if spots are absent then the area is noticeably duller than the crescent. *M. confusus* closely resembles some of the colour forms, but the bar of the eye in *mexicanus* is less strongly indicated and the dark pigment is more uniformly distributed. The resemblance to first instar *differentialis* is discussed under that species. Similar comparisons appear under the heading of *angustipennis* which hold for *stonei* as well.

The female genitalia are the same as described for *femur-rubrum*. The male genitalia are of value in the fourth and fifth instars. The notch at the tip of the subgenital plate is particularly useful, being duplicated only in *bruneri* and to some extent in *angustipennis*. The furculae are present and of moderate length (Plate IX, Figures 3C and 3D). The cerci differ from all other members of the group except *bruneri*.

Melanoplus bruneri Scud.

This species has been found to resemble in every respect the darker forms, at least, of *mexicanus*. It does not, however, infest fields, but prefers moderately open, shrubby locations in treed areas, and hence can be confused only with such individuals of *mexicanus* as are taken in that particular habitat.

Melanoplus confusus Scud.

This species closely resembles the less extreme forms of *mexicanus*. The ground colour is commonly buff to light brown, the dark brown and black pigment being generously distributed in large patches and small spots. Green forms have not been encountered during the period of the present study. The barring of the eye is more evident than in either *mexicanus* or *fasciatus*, but in the latter there is considerably more dark

pigment below the bar than above it, just as in *confusus*. The whitish pronotal crescent encroaches somewhat on the gena which is usually slightly darker in ground colour and contains a sprinkling of light brown spots.

The third valvulae of the ovipositor resemble those of *angustipennis* in having a high, angulate shoulder, and are therefore of some use in distinguishing fifth instar females, but there are no projections on the eighth sternite. Minute furculae are present in the fourth and fifth instar males. The cerci, bent dorsad and mesad at the tip (Plate XI, Figure 12A-D) differentiate the last 2 instars from the same stages of the other 6 species.

M. confusus is usually the first species to hatch in the spring, third instar individuals being encountered when *mexicanus* begins to hatch.

Melanoplus fasciatus (F. Walk.)

M. fasciatus does not differ greatly from *confusus*. The ground colour is more commonly pale yellow to cream, and reddish brown tints frequently mingle with the fuscous and black pigments. The dark pigment on the hind femur is commonly quite heavy, the cream coloured light areas showing up in strong contrast. This density of the pigment together with the tendency it exhibits to extend across the lower as well as the upper half of the femur, thus taking a V-shaped form, is typical of *fasciatus* but requires considerable practice before it can be used satisfactorily as a distinguishing character. The eye is not strongly barred, often not at all, but the lower part is much darker than the upper. The pronotal crescent is clearly indicated but on the gena it is sometimes moderately spotted with pale brown. It will be seen, then, that the species cannot be clearly distinguished from *confusus*. With practice, however, the difference in the barring of the eye, the greater contrast in the femoral and lateral markings, and the greater richness of colour, can be used with considerable degree of assurance.

The adult females commonly have a minute latero-posterior projection on the eighth sternite but this is of no value in the nymphs. The female genitalia in general are of the *femur-rubrum* type. Furculae are not present in the males. The cerci of this sex, are not very specific in shape but are quite long (Plate IX, Figures 2A-D).

The writer has found this species only in the pine woods (blueberry-bearberry habitat) and in bearberry patches adjacent to spruce trees, but Criddle (12) states that it is not confined to such locations.

Melanoplus infantilis Scud.

This species, together with *gladstoni* and to a large extent *occidentalis*, is strikingly characterized by the strong contrast of the darker markings against an expanse of pale cream ground colour, and by the almost complete absence of minute dark spots. The fuscous on the outer face of the posterior femur is regularly confined to the upper half. The eye is barred and noticeably darker below than above the bar. The pronotal crescent is margined by black above and by a few dark spots below but otherwise is not differentiated from the basal colour. The gena is unmarked by dark pigment. The only way in which the various instars of *infantilis* can be

separated with any degree of assurance from those of *gladstoni* is by the greater area of dark pigment occurring in the latter species in all parts except the frontal costa and adjacent edge of the clypeus which are darker in *infantilis* (Compare Figures 22 and 23 of Plate VIII.). Even this characteristic fails in a small percentage of individuals.

The female nymphs cannot be separated satisfactorily on a structural basis but the fourth and fifth instar male cerci are quite distinctive. In *infantilis* the tip is noticeably forked. This is not so evident in the fourth instar but the rudiment of the upper fork shows up as a definite angle, the same point in *gladstoni* being rounded; the lower margin is distinctly curved in the former species and almost straight in the latter. Moreover, in *infantilis* the cerci are slightly wider on the distal third than at the middle, while in *gladstoni* they are not.

Melanoplus gladstoni (Scud.)

M. gladstoni, as mentioned above, is strikingly similar to *infantilis*. It has a greater total area of dark pigment on the average and a more sharply defined bar on the eye, but the slight variation in these characters in both species renders them unsafe for use in diagnosis. The lower portion of the gena is occasionally rather dull. The markings of the frontal costa and usefulness of male genitalia have already been discussed.

This species develops much later than *infantilis*. Whereas the members of the latter species are nearly all mature by the end of June, fourth and fifth and occasionally third instar specimens of *gladstoni* can still be secured in early August.

Melanoplus occidentalis occidentalis (Thom.)

The nymphs of *occidentalis* were secured from adults collected in Alberta and it is perhaps unwise to compare them with Manitoba species. If this be permitted, however, it must be said that there is nothing in the colour pattern to separate this species sharply from *gladstoni* and *infantilis*. (The discoloration shown in Figure 11 of Plate VII was caused by the preservative). The femoral markings and eye character, within the limits of individual variation, are identical to those of the other species. On the average the darker shades cover a larger area and the pronotal crescent is commonly more sharply defined.

The female structures were not studied but, as shown in Plate XII, Figures 17A and B, the broad base of the cerci narrowing sharply backward and upward to the tip separates fourth and fifth instar males of *occidentalis* quite distinctly from those of the other 2 species.

TENTATIVE KEY TO ADULT FEMALES

The writer finds himself in agreement with Hebard (26) that "no satisfactory key for separating females of the species of *Melanoplus* can yet be supplied". The characters given in the following key, however, have been found very useful for the separation of females in Manitoba and can be applied to some extent to those of the fifth instar. For this reason it has been included here even though admittedly imperfect and not directly a part of the subject matter of this study.

Most of the characters have already been discussed in connection with the identification of nymphs. It might be well, however, to point out once more that many characters are not entirely constant, and frequently it is necessary to employ several in order to reach a maximum of accuracy. The first 2 major characters, wing length and shape of the upper valves of the ovipositor, require practice before they can be used with confidence, and since long-winged individuals are not uncommon in *fasciatus*, *borealis junius*, and *dawsoni* (especially *dawsoni* in Manitoba), this character does not place every individual of those species in its proper group. The two main types of upper valvulae are shown in Plate XII, Figures 18A and 19A, the former being the type with the rounded shoulder and the latter the high, square-shouldered type. Occasionally, however, (e.g., in *mexicanus*) the serrations of the rounded shoulder stand out sufficiently to resemble much too closely the second type, making it difficult to distinguish them until one has become reasonably familiar with the character. The light coloured mark at the base of the antenna, so useful in separating some species, is not usable in nymphs and is not entirely constant in adults. It begins inside and just below the antenna and curves, when continuous, upward and outward above the antenna. The remaining characters have already been fully discussed.

Keys to adult females of the genus *Melanoplus* have appeared before. A key to 11 species was published by Morse in 1898 (36), and again in 1920 (37) and reproduced in part by Walden (58). A key to the Montana species was issued by Mills and Pepper in 1938 (35).

M. differentialis is the only species of those treated below that does not occur in the province. No attempt at a "natural" arrangement has been made, nor is it intended that the key should separate all 19 species from other species not included.

1. Brachypterous species (tegmina and wings commonly shorter than abdomen)......(2)
   Macropterous species (tegmina and wings commonly extending beyond tip of abdomen)......(6)
2. Wings rounded at tip, very small; posterior margin of pronotum broadly rounded, margin of disk directly in line with margins of lateral lobes; small sylvan species confined mostly to areas of jack pine in Manitoba..........*M. islandicus* Blatch.
   Wings pointed at tip, variable in size; posterior margin of pronotal disk variable but not directly in line with posterior margin of lateral lobes....................(3)
3. Metasternal lobes separated by a distance at least equal their length; eyes separated at vertex by a distance of one and one-third times width of frontal costa at median ocellus; light mark at base of antenna broad, conspicuous, and continuous; large sylvan species associated with *islandicus*...........*M. huroni* Blatch.
   Metasternal lobes separated by a distance of less than their length; eyes separated at vertex by a distance not greater than width of frontal costa at median ocellus; light mark at base of antenna usually interrupted at centre, and if not then narrow and inconspicuous......................................(4)
4. Prongs of upper valvulae almost straight, their dorsal edges parallel with main axis of valvulae; latero-posterior projections of eight sternite absent; abdomen not ringed with shining black......................*M. borealis junius* (Dodge)
   Prongs of upper valvulae distinctly curved..................................(5)
5. Latero-posterior projections present on eighth sternite but very small; abdomen not ringed with shining black.......................*M. fasciatus* (F. Walker)
   Latero-posterior projections lacking on eighth sternite; abdomen ringed with shining black..*M. dawsoni* (Scud.)
6. Upper valvulae with high shoulders approximating a right angle (Plate XII, Figure 19A)..(7)
   Upper valvulae with rounded shoulders, or if approximating a right angle then distinctly serrate and shoulders not clearly defined..................................(11)

7. Latero-posterior projections of eighth sternite lacking..........................(8)
Latero-posterior projections present on eighth sternite..........................(9)

8. Prongs of upper valvulae short and not strongly curved; prosternal tubercle blunt with sides subparallel; light mark near base of antennae broad and continuous; longitudinal marks on outer face of posterior femur broken by transverse light marks.. *M. confusus* Scud.
Prongs of upper valvulae elongate and strongly curved; prosternal tubercle more or less pointed with sides convergent; light mark near base of antenna rarely continuous and if so then narrow; longitudinal marks on outer face of hind femur continuous *M. flavidus flavidus* Scud.

9. Length to tip of abdomen less than twenty-five millimetres; latero-posterior projections of eighth sternite small and inconspicuous; structures in general delicate *M. angustipennis* (Dodge)
Length more than 25 millimetres; latero-posterior projections of eighth sternite quite distinct; structures in general more robust..............................(10)

10. Tibiae mostly pink; general colour dark brown; contrastingly pale transverse marks on outer face of hind femur; confined to pine woods area in association with *M. islandicus*, etc.. *M. stonei* Rehn
Tibiae mostly glaucous; general colour light brown to gray-brown; transverse pale marks on outer face of hind femur either absent or inconspicuous *M. foedus foedus* Scud. *M. packardii* Scud.

11. Latero-posterior projections present on eighth sternite........................(12)
Latero-posterior projections of eighth sternite lacking........................(14)

12. Length to tip of abdomen less than 25 millimetres; latero-posterior projections of eighth sternite less than half as long as egg guide; general colour fuscous with innumerable minute gray maculations.............................. *M. gladstoni* (Scud.)
Length to tip of abdomen commonly much more than 25 millimetres; latero-posterior projections of eighth sternite at least half as long as egg guide; general colour yellow with sharply contrasting fuscous markings......................(13)

13. Latero-posterior projections half as long as egg guide; pronotal disk bordered by yellow stripes that continue on the tegmina; fuscous stripe on outer face of hind femur continuous and confined to upper half.................. *M. bivittatus* (Say)
Latero-posterior projections as long as egg guide; pronotal disk and tegmina without yellow stripes; fuscous on outer face of hind femur commonly replaced by yellow on posterior margin of each chevron, and always encroaching on lower half of femur.................................... *M. differentialis* (Thom.)

14. Lighter mark near base of antenna continuous; outer face of hind femur without transverse light bands or spots....................................(15)
Lighter mark near base of antenna interrupted at middle; outer face of hind femur with transverse light bands or spots..................................(16)

15. Outer face of hind femur covered with heavy fuscous, lighter marks occasionally encroaching slightly on upper margin; prongs of upper valvulae curved but slightly; prosternal tubercle of medium length, sides slightly to distinctly converging *M. keeleri luridus* (Dodge)
Outer face of hind femur typically bluish gray; prongs of upper valvulae strongly curved; prosternal tubercle long, blunt, sides subparallel on distal third, and pointing well back to hide rest of sternum; cerci with concave sides tapering to slender tip (see *mexicanus*).............. *M. femur-rubrum femur-rubrum* (DeG.)

16. Length to tip of abdomen usually much more than 20 millimetres................(17)
Length less than 20 millimetres..(18)

17. Distribution general; prosternal tubercle commonly short, vertical at least posteriorly, sides distinctly converging, tip more or less pointed; cerci comparatively broad, sides convex (see *femur-rubrum*)............. *M. mexicanus mexicanus* (Sauss.)
Confined to shrubby or wooded areas; otherwise not clearly differentiated from *mexicanus*... .... *M. bruneri* Scud.

18. Caudal tibiae pink; general colour dark brown to fuscous above, bright yellow beneath; comparatively robust.................................. *M. dawsoni* (Scud.)

19. Caudal tibiae glaucous; general colour brown to yellowish brown above, pale yellow or cream beneath; comparatively slender and delicately constructed *M. infantilis* Scud.

SUMMARY

Twenty-one species of *Melanoplus*, 18 of them from Manitoba, are described and compared.

A few of these can be identified in all instars by means of a single characteristic. A few others cannot be separated at all, or at best only in their more typical form. With care, however, the majority can be distinguished on the basis of a combination of colour markings, structural features, and other characteristics.

In all except a few species, the later instars are the more easily identified, first instar specimens nearly always offering considerable difficulty.

No structural characters have been discovered that are diagnostic in the first 2 instars. A few third instar males can be identified by means of such characters, as can also most males of the fourth and fifth instars. Fifth instar females, and to a lesser extent the fourth, can usually be *grouped* quite satisfactorily by means of structure but can rarely be identified *to species* on that basis.

Differences in colour are of moderate value in a few species but are unreliable in the majority of species.

Colour pattern, although more or less variable depending on the species, is surprisingly reliable in most instances and is the only means of characterizing all instars and both sexes on a uniform basis.

The most useful patterns are those on the posterior femora, the lateral lobes of the pronotum, the genae, and the compound eyes. The relative proportion and manner of distribution of the light and dark pigments as a whole is also of definite value.

A knowledge of seasonal life-history, distribution, habitat, and food preferences, sometimes makes possible the separation of species otherwise indistinguishable.

The value of a properly preserved reference collection cannot be overemphasized. An excellent series can be built up by weekly collections in selected habitats, the earlier instars being identified by comparison with the later stages.

The sexes are readily differentiated in all stages, but it is possible in the first instar to overlook the rudiments of the lower valvulae, and when this is done all specimens appear to be males.

The number of antennal segments serve best to distinguish the first three normal instars, and the nature of the wing pads differentiates the fourth and fifth instars from each other and from the earlier stages.

A tentative key to 19 species of adult females is included.

It is hoped that the work may be continued and expanded. Suggestions are given as to structures that are deserving of further study.

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PLATE I. Development of Wing Pads (×11).

FIGURES 1–5. Instars 1–5 of *M. femur-rubrum femur-rubrum* (DeG.).
FIGURE 6. Fifth instar of *M. islandicus* Blatch.

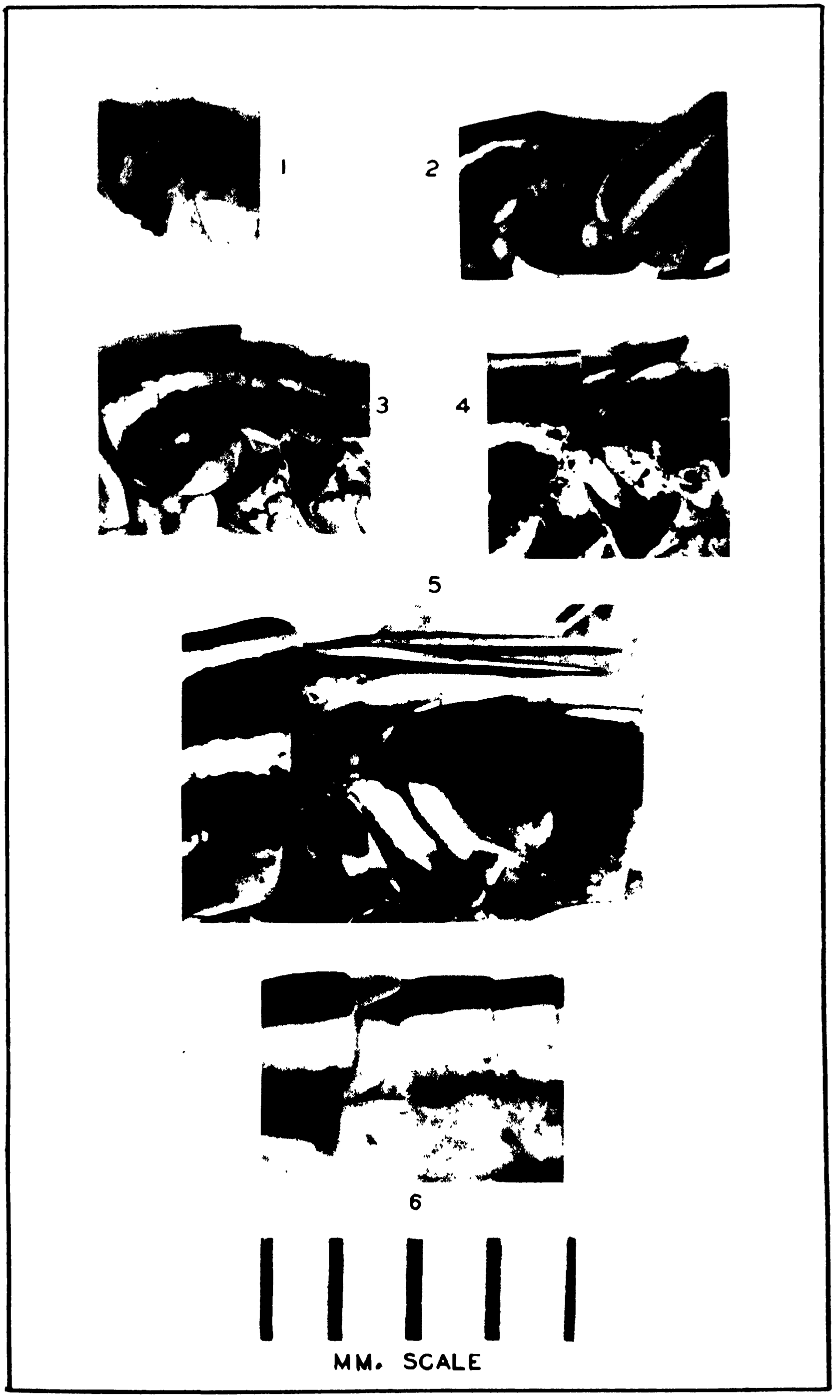
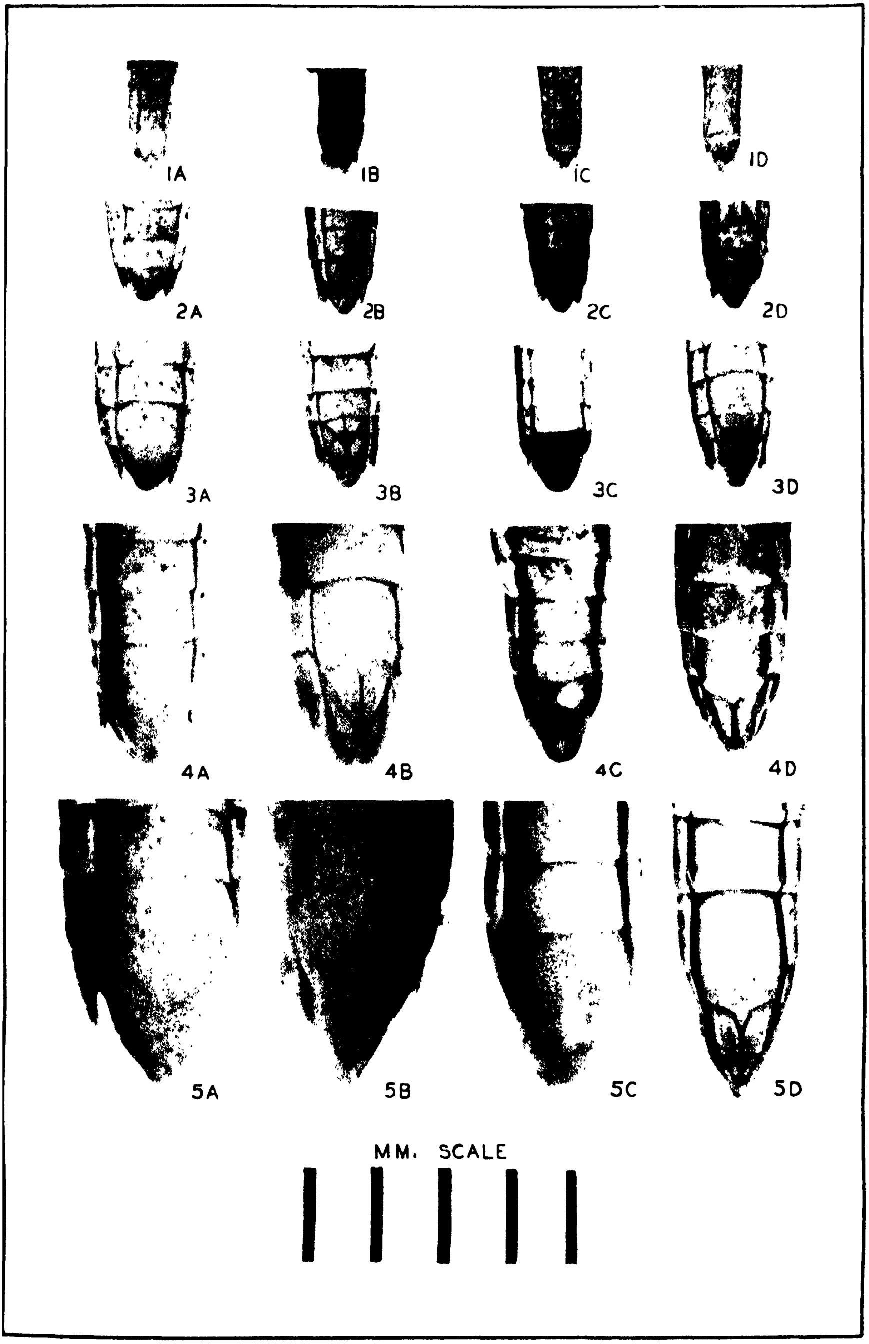

1
2
3
4
5
6
MM. SCALE

PLATE II. Development of Subgenital Plate and Ovipositor (× 11).

FIGURES 1A–5A. ♂♂ of *M. bivittatus* (Say).
FIGURES 1B–5B. ♀♀ of *M. bivittatus* (Say).
FIGURES 1C–5C. ♂♂ of *M. femur-rubrum femur-rubrum* (DeG.).
FIGURES 1D–5D. ♀♀ of *M. femur-rubrum femur-rubrum* (DeG.).


1A
1B
1C
1D
2A
2B
2C
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3A
3B
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3D
4A
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4C
4D
5A
5B
5C
5D
MM. SCALE

PLATE III*. First Instar Nymphs (× 9).

FIGURE 1. *M. keeleri luridus* (Dodge). Preserved ♀.
FIGURE 2 *M. dawsoni* (Scud.). Preserved ♀.
FIGURE 3. *M. bivittatus* (Say). Preserved ♀.
FIGURE 4. *M. femur-rubrum femur-rubrum* (De G.). Preserved ♀.
FIGURE 5. *M. islandicus* Blatch. Preserved ♂.
FIGURE 6. *M. borealis junius* (Dodge). Fresh ♀.
FIGURE 7. *M. bowditchi canus* Hebard. Fresh ♀.
FIGURE 8. *M. flavidus flavidus* Scud. Fresh ♀.

* In photographing the specimens shown as Figure 6 of this plate, Figure 5 of Plate IV, and Figures 1 and 2 of Plate V a more contrasting type of film was used. Unfortunately when the supply was exhausted no more of this type could be procured. This should be borne in mind when these figures are compared with any of the remaining ones.

PLATE III

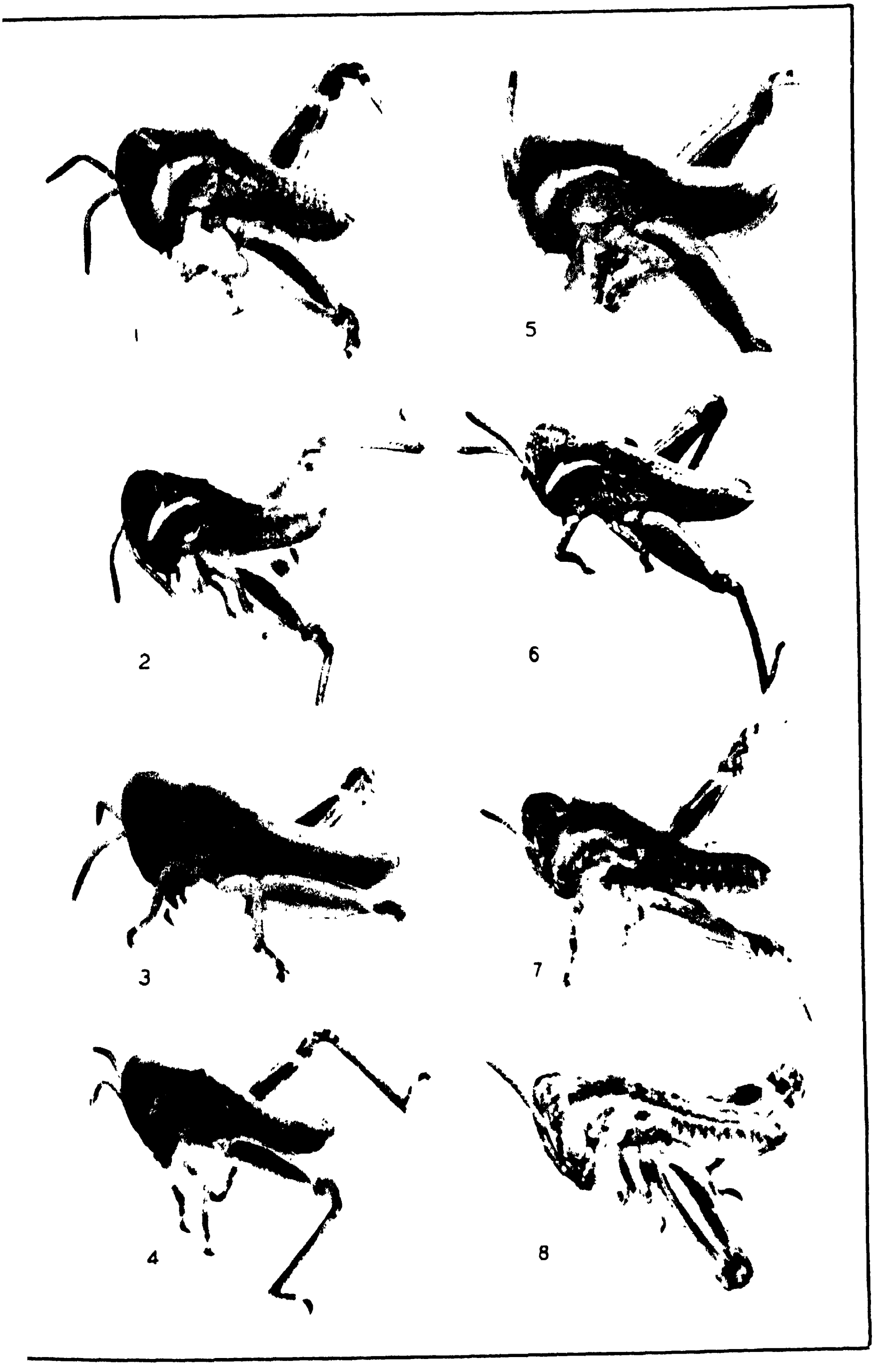

Plate IV. First Instar Nymphs ($\times$ 9)

Figure 1. *M. gladstoni* (Scud.). Fresh ♀.
Figure 2. *M. infantilis* Scud. Preserved ♀.
Figure 3. *M. occidentalis occidentalis* (Thom.). Preserved ♀.
Figure 4. *M. huroni* Blatch. Preserved ♀.
Figure 5. *M. bruneri* Scud. Fresh ♀.
Figure 6. *M. mexicanus mexicanus* (Sauss.). Preserved ♀.
Figure 7. *M. mexicanus mexicanus* (Sauss.). Fresh ♂.
Figure 8. *M. differentialis* (Thom.). Fresh ♀.

PLATE IV

PLATE V. First Instar Nymphs (× 9).

FIGURE 1. *M. confusus* Scud. Fresh ♀.
FIGURE 2. *M. stonei* Rehn. Fresh ♀.
FIGURE 3. *M. foedus foedus* Scud. Fresh ♀.
FIGURE 4. *M. fasciatus* (F. Walk.). Fresh ♂.
FIGURE 5. *M. angustipennis* (Dodge). Fresh ♂.
FIGURE 6. *M. packardii* Scud. Fresh ♀.

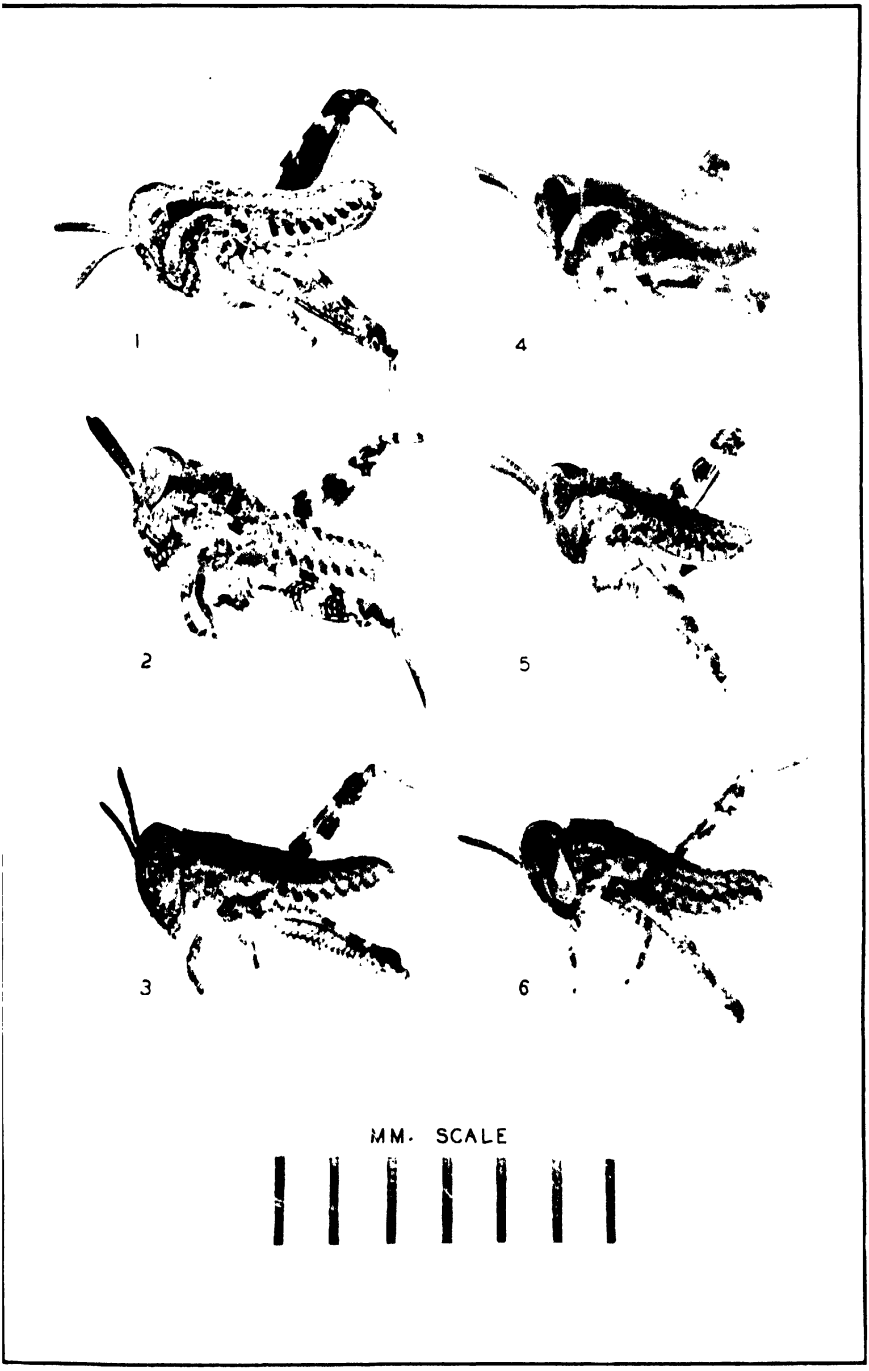

Plate VI. Fourth Instar Males (× 3) (Preserved material).

Figure 1. *M. keeleri luridus* (Dodge).
Figure 2. *M. dawsoni* (Scudder).
Figure 3. *M. femur-rubrum femur-rubrum* (DeG.).
Figure 4. *M. bivittatus* (Say).
Figure 5. *M. differentialis* (Thom.).
Figure 6. *M. islandicus* Blatch.
Figure 7. *M. borealis junius* (Dodge).
Figure 8. *M. bowditchi canus* Hebard.
Figure 9. *M. flavidus flavidus* Scud.

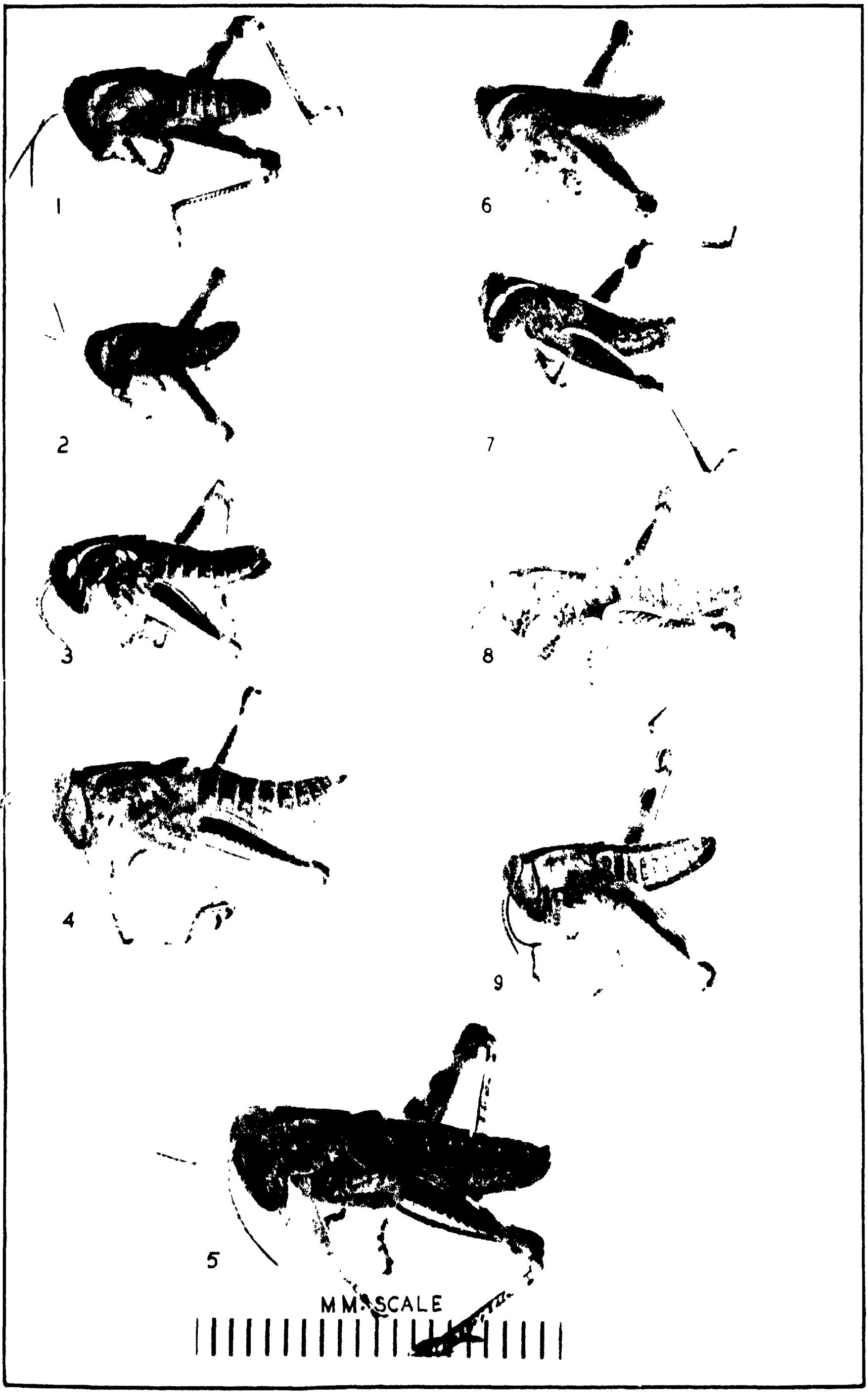
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PLATE VII. Fourth Instar Males (× 3) (Preserved material)

FIGURE 1. *M. huroni* Blatch.
FIGURE 2. *M. stonei* Rehn.
FIGURE 3. *M. angustipennis* (Dodge).
FIGURE 4. *M. foedus foedus* Scud.
FIGURE 5. *M. packardii* Scud.
FIGURE 6. *M. bruneri* Scud.
FIGURE 7. *M. confusus* Scud.
FIGURE 8. *M. fasciatus* (F. Walk.).
FIGURE 9. *M. infantilis* Scud.
FIGURE 10. *M. gladstoni* (Scud.).
FIGURE 11. *M. occidentalis occidentalis* (Thom.).
FIGURE 12. *M. mexicanus mexicanus* (Sauss.)

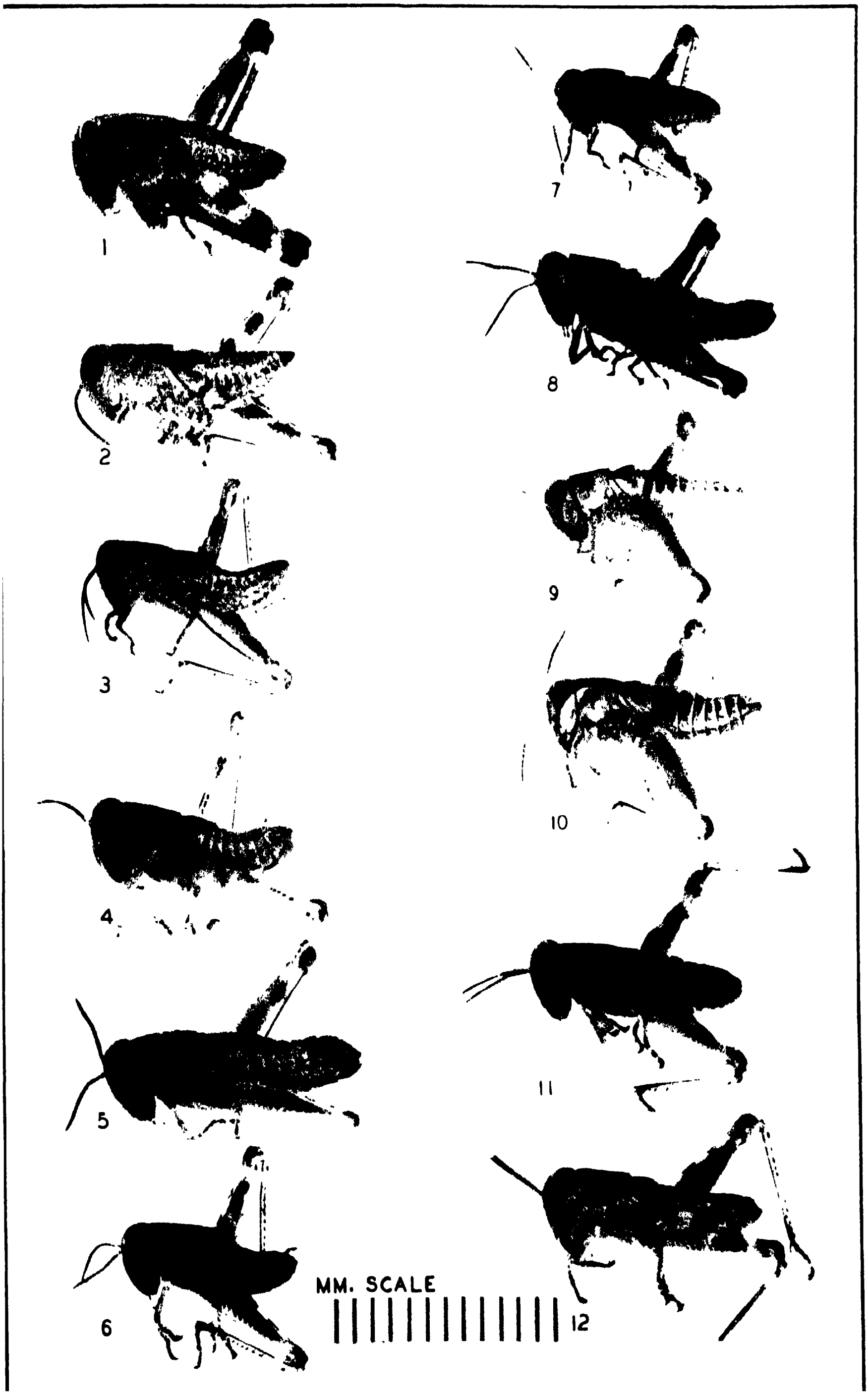
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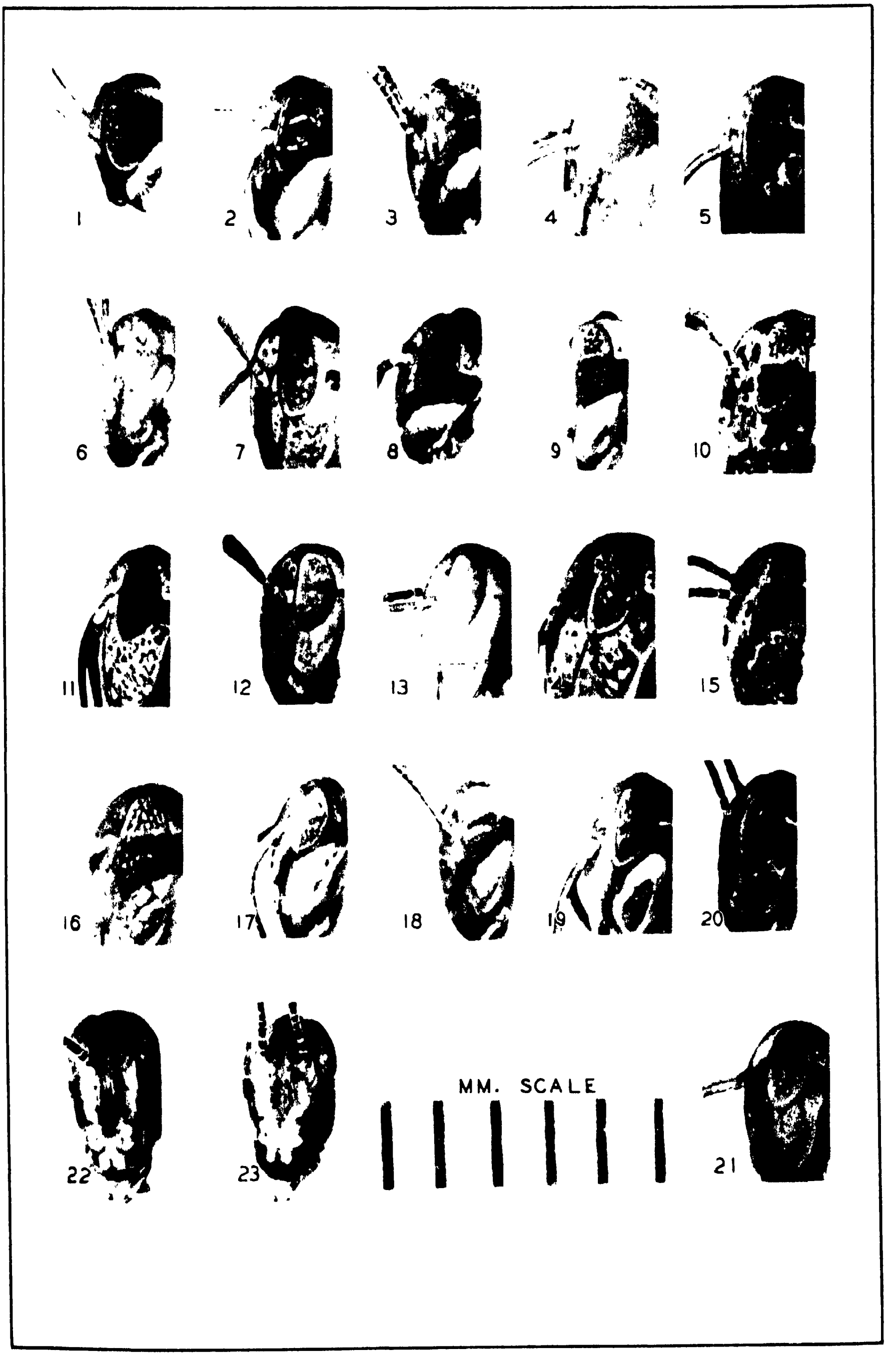
Plate VIII. Figures 1–21. Eyes of Third Instar Females (× 9). Figs. 22 and 23. Frontal Views (Preserved material).

Figure 1. *M. dawsoni* (Scud.).
Figure 2. *M. keeleri luridus* (Dodge).
Figure 3. *M. femur-rubrum femur-rubrum* (DeG.).
Figure 4. *M. bivittatus* (Say).
Figure 5. *M. differentialis* (Thom.).
Figure 6. *M. flavidus flavidus* Scud.
Figure 7. *M. bowditchi canus* Hebard.
Figure 8. *M. borealis junius* (Dodge).
Figure 9. *M. islandicus* Blatch.
Figure 10. *M. huroni* Blatch.
Figure 11. *M. stonei* Rehn.
Figure 12. *M. angustipennis* (Dodge).
Figure 13. *M. foedus foedus* Scud.
Figure 14. *M. packardii* Scud.
Figure 15. *M. confusus* Scud.
Figure 16. *M. fasciatus* (F. Walk.).
Figure 17. *M. infantilis* Scud.
Figure 18. *M. gladstoni* (Scud.).
Figure 19. *M. occidentalis occidentalis* (Thom.).
Figure 20. *M. mexicanus mexicanus* (Sauss.).
Figure 21. *M. bruneri* Scud.
Figure 22. *M. infantilis* Scud.
Figure 23. *M. gladstoni* (Scud.).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MM. SCALE
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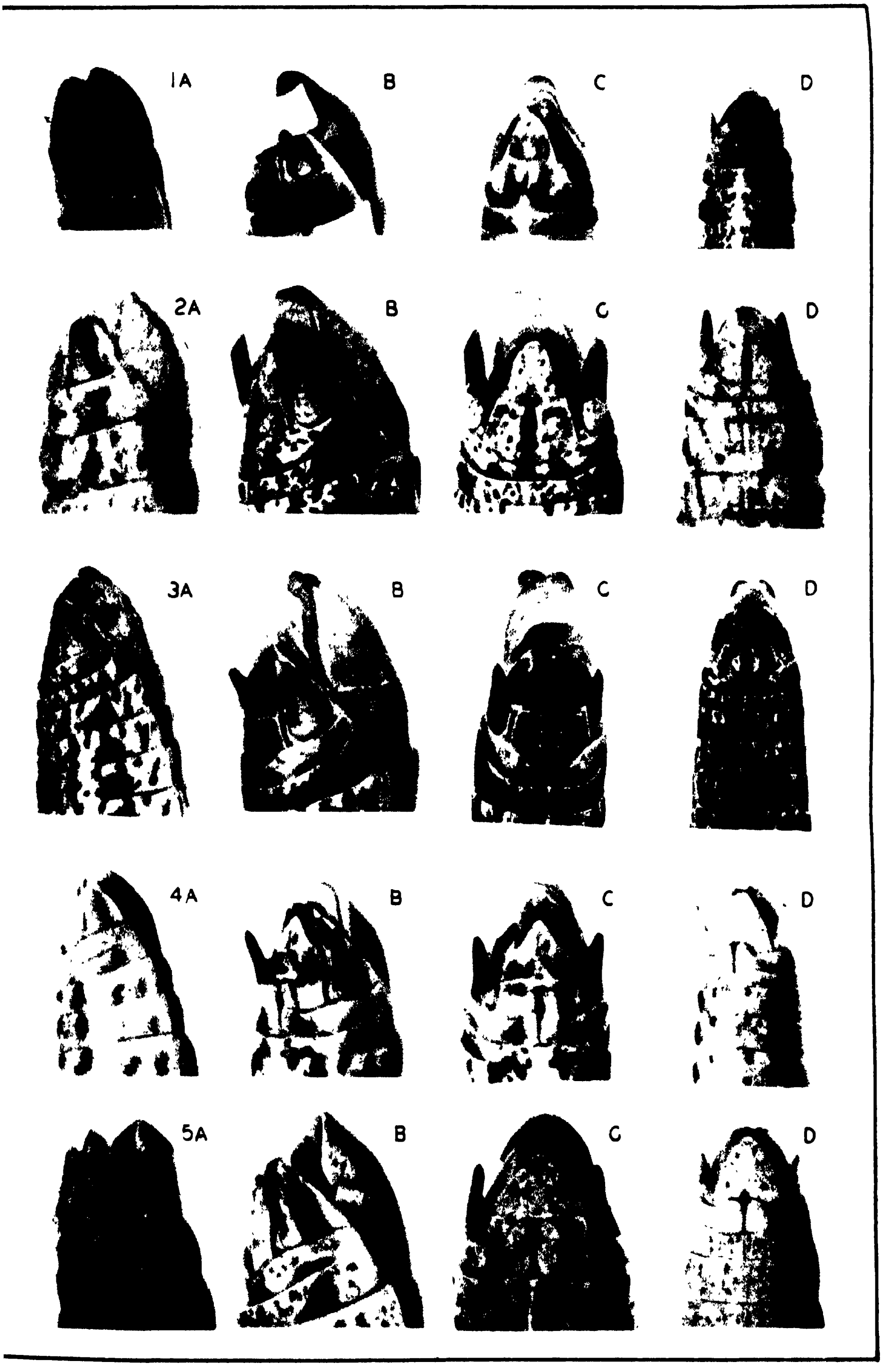
PLATE IX. Fourth and Fifth Instar Male Genitalia (× 11).

FIGURE 1A. *M. dawsoni* (Scud.). Fourth lateral.
FIGURE 1B. *M. dawsoni* (Scud.). Fifth lateral.
FIGURE 1C. *M. dawsoni* (Scud.). Fifth dorsal.
FIGURE 1D. *M. dawsoni* (Scud.). Fourth dorsal.
FIGURE 2A. *M. fasciatus* (F. Walk.). Fourth lateral.
FIGURE 2B. *M. fasciatus* (F. Walk.). Fifth lateral.
FIGURE 2C. *M. fasciatus* (F. Walk.). Fifth dorsal.
FIGURE 2D. *M. fasciatus* (F. Walk.). Fourth dorsal.
FIGURE 3A. *M. mexicanus mexicanus* (Sauss.). Fourth lateral.
FIGURE 3B. *M. mexicanus mexicanus* (Sauss.). Fifth lateral.
FIGURE 3C. *M. mexicanus mexicanus* (Sauss.). Fifth dorsal.
FIGURE 3D. *M. mexicanus mexicanus* (Sauss.). Fourth dorsal.
FIGURE 4A. *M. flavidus flavidus* Scud. Fourth lateral.
FIGURE 4B. *M. flavidus flavidus* Scud. Fifth lateral.
FIGURE 4C. *M. flavidus flavidus* Scud. Fifth dorsal.
FIGURE 4D. *M. flavidus flavidus* Scud. Fourth dorsal.
FIGURE 5A. *M. bowditchi canus* Hebard. Fourth lateral.
FIGURE 5B. *M. bowditchi canus* Hebard. Fifth lateral.
FIGURE 5C. *M. bowditchi canus* Hebard. Fifth dorsal.
FIGURE 5D. *M. bowditchi canus* Hebard. Fourth dorsal.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4A
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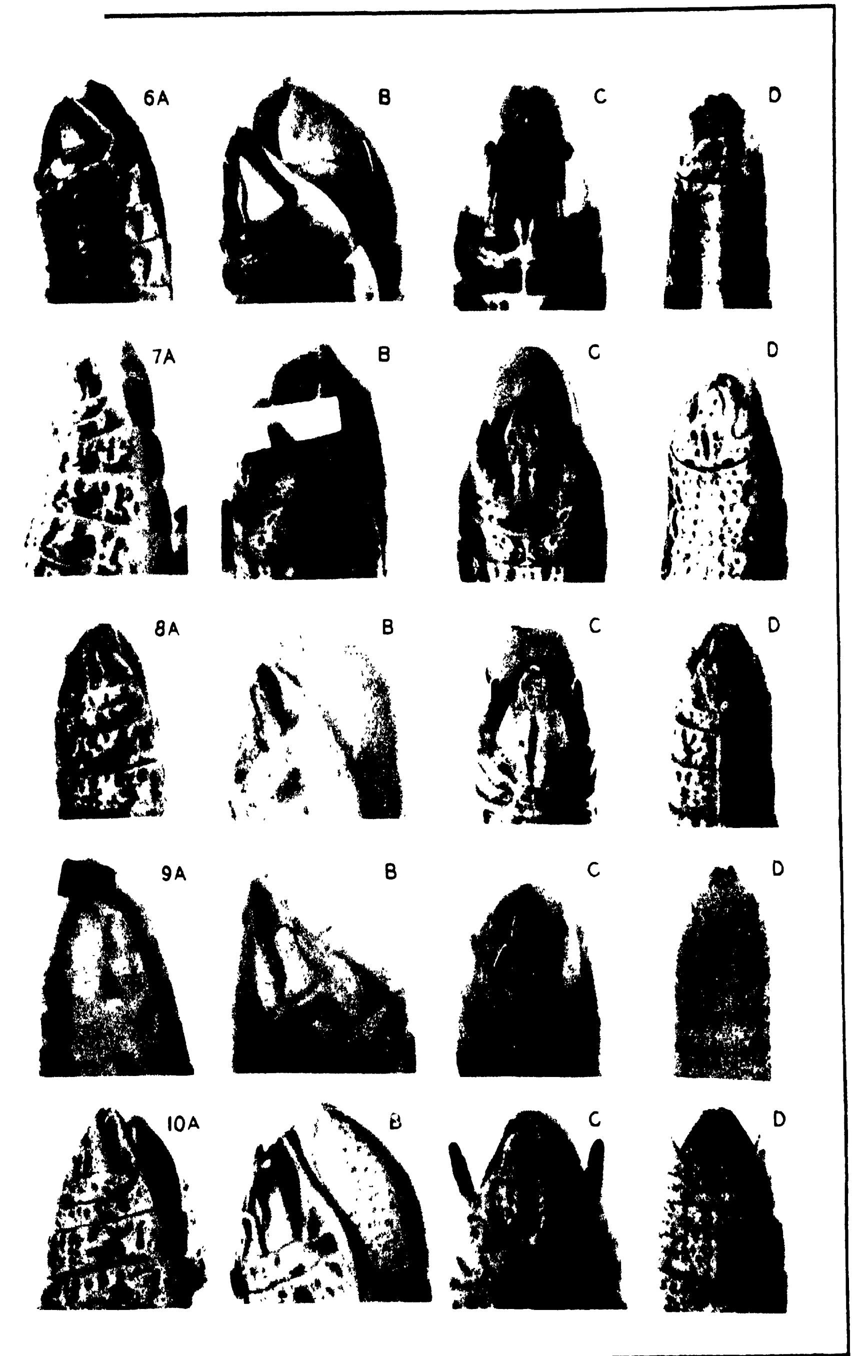
D

PLATE X. Fourth and Fifth Instar Male Genitalia (× 11).

FIGURE 6A *M. femur-rubrum femur-rubrum* (DeG.). Fourth lateral.
FIGURE 6B. *M. femur-rubrum femur-rubrum* (DeG.). Fifth lateral.
FIGURE 6C. *M. femur-rubrum femur-rubrum* (DeG.). Fifth dorsal.
FIGURE 6D. *M. femur-rubrum femur-rubrum* (DeG.). Fourth dorsal.
FIGURE 7A. *M. borealis junius* (Dodge). Fourth lateral.
FIGURE 7B. *M. borealis ujnius* (Dodge). Fifth lateral.
FIGURE 7C. *M. borealis junius* (Dodge). Fifth dorsal.
FIGURE 7D. *M. borealis junius* (Dodge). Fourth dorsal.
FIGURE 8A. *M. angustipennis* (Dodge). Fourth lateral.
FIGURE 8B. *M. angustipennis* (Dodge). Fifth lateral.
FIGURE 8C. *M. angustipennis* (Dodge). Fifth dorsal.
FIGURE 8D. *M. angustipennis* (Dodge). Fourth dorsal.
FIGURE 9A. *M. foedus foedus* Scud. Fourth lateral.
FIGURE 9B. *M. foedus foedus* Scud. Fifth lateral.
FIGURE 9C. *M. foedus foedus* Scud. Fifth dorsal.
FIGURE 9D. *M. foedus foedus* Scud. Fourth dorsal.
FIGURE 10A. *M. packardii* Scud. Fourth lateral.
FIGURE 10B. *M. packardii* Scud. Fifth lateral.
FIGURE 10C. *M. packardii* Scud. Fifth dorsal.
FIGURE 10D. *M. packardii* Scud. Fourth dorsal.


6A
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9A
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10A
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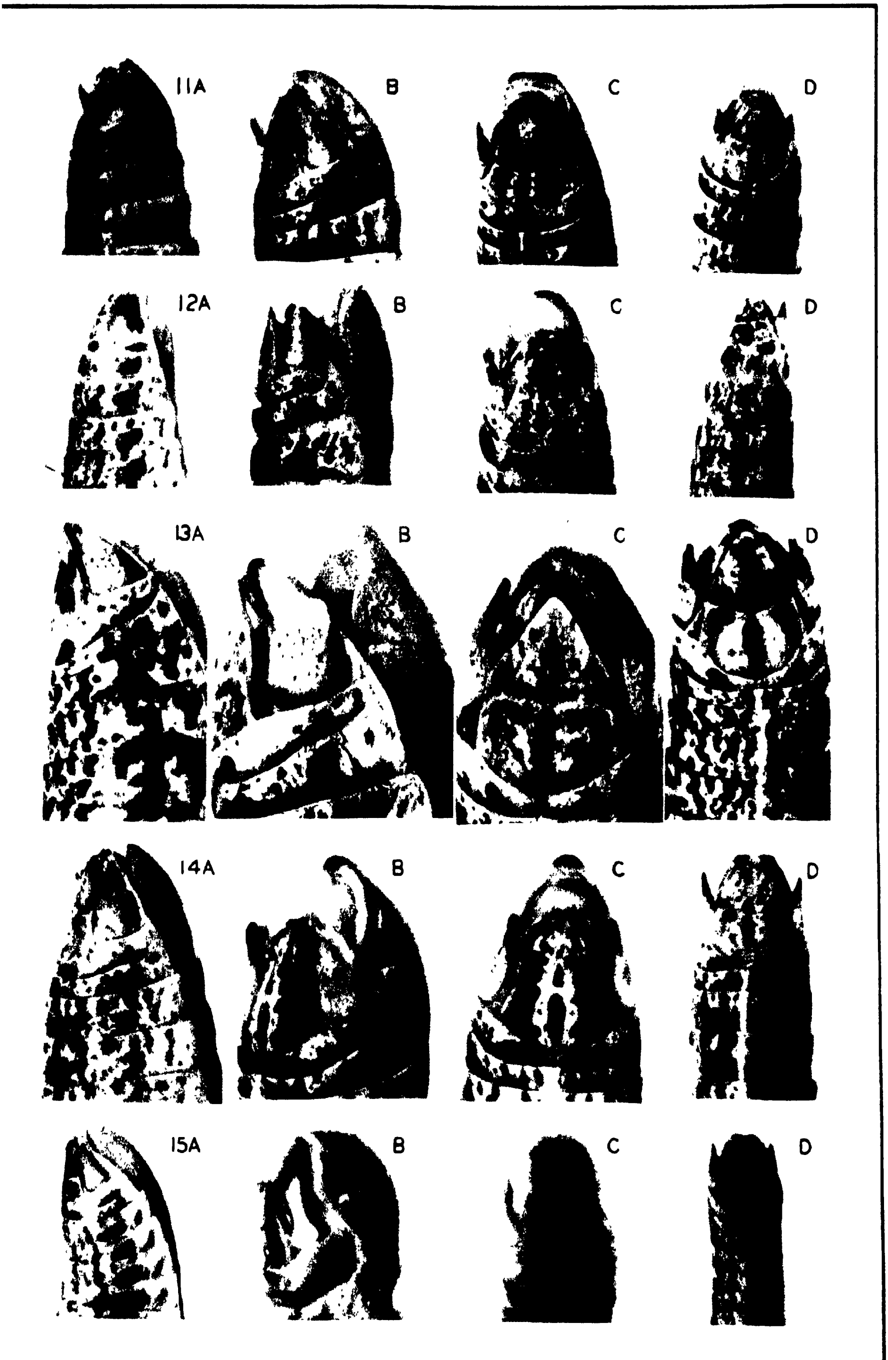
C
D

PLATE XI. Fifth and fifth Instar Male Genitalia (× 11).

FIGURE 11A. *M. keeleri luridus* (Dodge). Fourth lateral.
FIGURE 11B. *M. keeleri luridus* (Dodge). Fifth lateral.
FIGURE 11C. *M. keeleri luridus* (Dodge). Fifth dorsal.
FIGURE 11D. *M. keeleri luridus* (Dodge). Fourth dorsal.
FIGURE 12A. *M. confusus* Scud. Fourth lateral.
FIGURE 12B. *M. confusus* Scud. Fifth lateral.
FIGURE 12C. *M. confusus* Scud. Fifth dorsal.
FIGURE 12D. *M. confusus* Scud. Fourth dorsal.
FIGURE 13A. *M. differentialis* (Thom.). Fourth lateral.
FIGURE 13B. *M. differentialis* (Thom.). Fifth lateral.
FIGURE 13C. *M. differentialis* (Thom.). Fifth dorsal.
FIGURE 13D. *M. differentialis* (Thom.). Fourth dorsal.
FIGURE 14A. *M. bivittatus* (Say). Fourth lateral
FIGURE 14B. *M. bivittatus* (Say). Fifth lateral.
FIGURE 14C. *M. bivittatus* (Say). Fifth dorsal.
FIGURE 14D. *M. bivittatus* (Say). Fourth dorsal.
FIGURE 15A. *M. infantilis* Scud. Fourth lateral.
FIGURE 15B. *M. infantilis* Scud. Fifth lateral.
FIGURE 15C. *M. infantilis* Scud. Fifth dorsal.
FIGURE 15D. *M. infantilis* Scud. Fourth dorsal.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15A
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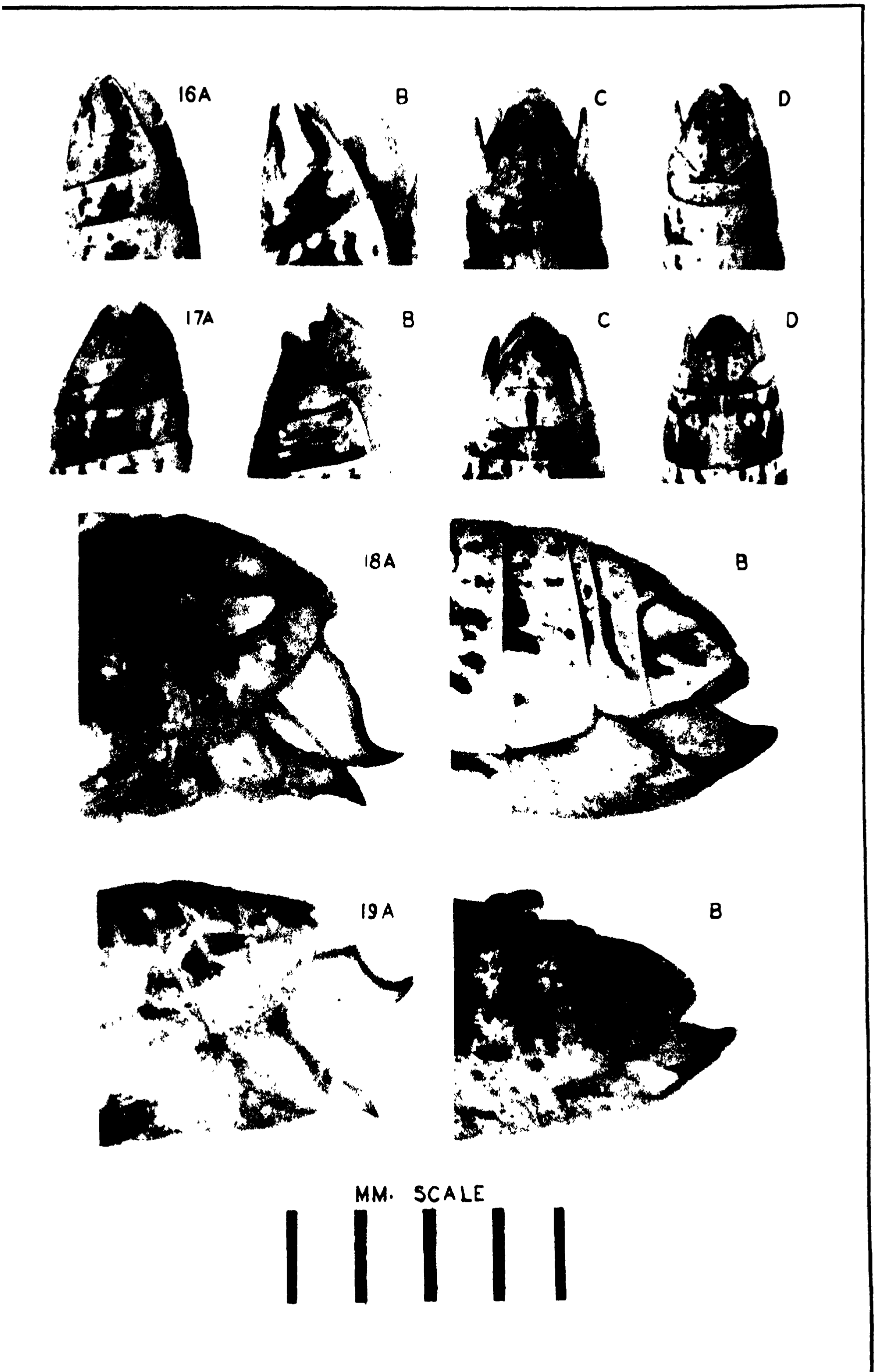
C
D

PLATE XII. Male and Female Genitalia (× 11).

FIGURE 16A. *M. gladstoni* (Scud.). Fourth ♂ lateral.
FIGURE 16B. *M. gladstoni* (Scud.). Fifth ♂ lateral.
FIGURE 16C. *M. gladstoni* (Scud.). Fifth ♂ dorsal.
FIGURE 16D. *M. gladstoni* (Scud.). Fourth ♂ dorsal.
FIGURE 17A. *M. occidentalis occidentalis* (Thom.). Fourth ♂ lateral.
FIGURE 17B. *M. occidentalis occidentalis* (Thom.). Fifth ♂ lateral.
FIGURE 17C. *M. occidentalis occidentalis* (Thom.). Fifth ♂ dorsal.
FIGURE 17D. *M. occidentalis occidentalis* (Thom.). Fourth ♂ dorsal.
FIGURE 18A. *M. differentialis* (Thom.). Adult ♀ lateral.
FIGURE 18B. *M. differentialis* (Thom.). Fifth ♀ lateral.
FIGURE 19A. *M. angustipennis* (Dodge). Adult ♀ lateral.
FIGURE 19B. *M. angustipennis* (Dodge). Fifth ♀ lateral.


16A
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18A
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19A
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MM. SCALE

BOOK REVIEW

New Crops for the New World. Edited by Charles Morrow Wilson. 295 pp., 32 plates. The Macmillan Company, New York. 1945. $4.50.

This volume discusses in popular form the introduction and development of new crops in America. Emphasis is placed almost entirely on crops that can be produced in South and Central America, or, in a few instances, on plants native to these areas, which may be grown in southern United States.

The term crops is not limited to plants and plant products but includes livestock and animal products, such as silk. With the exception of brief introductions by the Editor the text has been prepared by specialists in various fields.

Wilson Popenoe discusses tropical fruits and cinchona; Edgar Anderson, maize; Albert O. Rhoad, livestock breeds; Miriam L. Bomhard, palm oils and waxes; Walter N. Bangham, rubber; E. C. Higbee, drug and medicinal crops; C. P. Clausen, biological control of insect pests; Arthur Bevan, forest resources; George E. Adames, silk; Atherton Lee, bamboos; A. T. Erwin, peppers; B. Y. Morrison, flowers and the problems of plant introduction; P. Honig, cane sugar; and V. C. Dunlap, miscellaneous fibre and oil plants and timber trees.

As might be expected in a work of this kind where so many authors are involved the treatment of the subject matter tends to lack uniformity. From the standpoint of the popular reader some sections are exceedingly well done. For example, the story of silkworm culture in Brazil is told in an eminently readable narrative style which presents most of the significant data without becoming pedantic. Other sections do not appeal nearly so much to the average reader.

Work which has been done during the war on stimulating the production of rubber, cinchona, and various fibres in America is especially emphasized.

The volume is somewhat lacking in coherence and appears to have been rather hastily edited since one notes a considerable number of typographical errors. There are a number of excellent photographs illustrating the crops under discussion.

From the point of view of the agriculturalist of Canada or northern United States (which after all is part of the "New World") the volume contains relatively little of immediate concern. As a popular study of economic botany and the shifting of crops from one part of the world to another the compilation will be of interest to a wide range of readers.

Harold A. Senn.

SCIENTIFIC AGRICULTURE

VOLUME 26 MAY, 1946 No. 5

ERADICATION OF POISON IVY (*RHUS RADICANS* L.)

I. EXPERIMENTS WITH SODIUM CHLORATE, SODIUM CHLORIDE, AND TWO PETROLEUM OILS[1]

W. H. Minshall[2]

Science Service, Ottawa, Canada

[Received for publication March 2, 1946]

Every summer dermatitis, caused by poison ivy, is responsible for considerable discomfort and, in some cases, loss of time. In spite of the ever existing danger of poisoning, however, there has been no organized effort at eradication. From the limited literature giving experimental results, there would appear to be a paucity of published data on the eradication of poison ivy with herbicides.

Hansen (9) reported the destruction of poison ivy with thorough applications of sodium chlorate. Pieper and Hackleman (18) concluded from two years' results that poison ivy could be eliminated from orchards by the use of chlorates or ammonium thiocyanate but complete eradication was apparently not obtained in the experiments reported. Beach (2) investigated the effect of 5 rates of application of sodium chlorate to poison ivy growing beneath apple trees. He found that single applications of 3 pounds per square rod gave an excellent kill of poison ivy. Heavier applications injured the trees. In the papers of Howitt and Gammon (11, 12, 13) and of Willard (22), general results or recommendations based on results are given for the application of chlorates to poison ivy but no experimental details are included. A large number of publications including Adams (1), Crooks and Kephart (3), Eseltine (4), Fiske (5, 6), Grant and Hansen (7), Groh (8), Harlow (10), Kephart (14), Maguire (15), Muenscher (16), Robbins, Crafts and Raynor (19), Steinbauer and Steinmetz (20), and Stoddard (21) give recommendations for the eradication of poison ivy but whether or not these are based on experimental results is not stated.

To obtain information on the eradication of poison ivy, under conditions prevailing at Ottawa, Canada, the experiments herein reported were undertaken in 1935. Although not elaborate in design, close observations were made throughout the duration of the experiments, and for several years following the final application. All treatments were carried out on small plots, with simple equipment, (Plate I, Figure 1), and under conditions easily duplicated by owners of small properties.

EXPERIMENTAL METHODS

The herbicides investigated were sodium chlorate, sodium chloride (common salt), and the petroleum oils, furnace fuel oil, and a water white kerosene with the trade name of longtime burning oil. Three types of

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applications were made: spray, sprinkle, and dry salt. For the spray treatments a knapsack sprayer of 3-gallon capacity was used. For the sprinkle experiments applications were made with a sprinkling can of $1\frac{3}{4}$-gallon capacity supplied with a rose 3 inches in diameter with 41 perforations each approximately $\frac{1}{16}$ of an inch in diameter. In dry salt applications the material was broadcast by hand over the plot. If the amount of herbicide to be applied was less than 5 pounds it was thoroughly mixed with sufficient dry sand to bring the total to this amount. In the majority of the experiments the applications were made in the late afternoon.

All experimental plots were in the vicinity of Ottawa West, Ontario, on very shallow Farmington loam over limestone bedrock. Stones were numerous on the surface of many of the plots.

Estimates of the percentage cover of poison ivy were made visually before and after each application. They were made throughout by the same operator and represent ground cover, that is, the percentage of the area of the plot covered with poison ivy foliage. They do not take into account the density of the foliage in those areas covered with poison ivy.

RESULTS

A résumé of experimental details and the results obtained will be found in Table 1.

Sodium Chloride

Spray. (Table 1. Exp. 8, Plot 4.)

A total of 14 applications, each of 3 pounds of salt dissolved in 1 gallon of water, applied over a 5-year period to a plot of 1 square rod in area, reduced the poison ivy cover from 85% to 13%. The checking of growth was of temporary duration however, since by the second year after the last treatment the ivy had recovered to 60%.

Sprinkle. (Table 1. Exp. 8, Plot 7.)

A similar number of applications over the same period but consisting of 6 pounds salt in 2 gallons water and made with a sprinkling can reduced the poison ivy from 85% to 3%. The control was more permanent here as the stand had only increased to 10% of ground cover in the second summer after the last treatment.

With both the spray and sprinkle applications of common salt, each treatment killed the majority of the ivy leaves, provided the weather remained dry. New leaves were soon produced, however, and the next treatment could be made 5 to 6 weeks later. Some of the treatments were washed off by rain and thus did not affect the ivy foliage. The better control obtained with the sprinkling can no doubt can be explained by the effect of the large amount of salt on the underground rootstocks. In the later treatments, when the stand had been thinned out considerably, the major part of the 2 gallons was applied to those plants still present. Thus the 84 pounds, the total for all applications, was not applied evenly to the plot as a whole but was concentrated around the underground stems and no doubt acted as a sterilizing agent.

Dry Salt. (Table 1. Exp. 10, Plots 12–15, and Exp. 11, Plots 1–5.)

Applications of common salt broadcast by hand on October 7, 1936, even when as heavy as 100 pounds per square rod, had no effect on poison ivy. In the summer following the applications, there was no noticeable difference between the untreated check areas and those treated with common salt.

Weather data provided by the Field Husbandry Division, Central Experimental Farm, Ottawa, characterize 1936 as a very wet open fall. During October, rain fell on 16 days for a total precipitation of 5.14 inches (0.27 inches fell as snow) as compared with the 50-year average precipitation of 2.59 inches (0.04 falling as snow). All the snow that fell during October and November melted on the ground and as late as December 16 the fields were three-quarters bare. As a result, no salt was visible above ground on any of the plots 14 days after the applications were made. The salt was no doubt leached from the soil before affecting the poison ivy.

Applications made in June gave somewhat better results in that 40 pounds common salt reduced the poison ivy in a square rod plot from 70% to 20%, and 60 pounds reduced the ivy cover from 50% to 15%. Neither 10 nor 20 pound applications on similar areas had any effect.

Petroleum Oils

Sprinkle. (Table 1. Exp. 8, Plot 6.) Eleven applications, each (except the final one) consisting of 2 gallons furnace fuel oil applied with a sprinkling can to 1 square rod of poison ivy, over a 5-year period, reduced the poison ivy cover from 85% to 3%. Each application killed all the leaves present regardless of whether it rained afterward or not. However, new leaves soon appeared. The reduction in stand was gradual over the 5-year period and the plants were quite small during the latter part. The grass was killed by the first application so the only plants present during remainder of treatment, other than poison ivy, were such coarse weeds as *Melilotus alba* Desr., *Lactuca scariola* L., *Linaria vulgaris* Hill, *Hypericum perforatum* L., etc. As a result, the plot was unsightly.

Spray. (Table 1, Exps. 13 and 14.)

Applications of a water white kerosene, made with a knapsack sprayer at the rate of 2 gallons per square rod, in the month of June, had very little effect on the poison ivy present whether applied to the upper or under surface of the leaves. A few of the young ivy leaves developed brown curled edges following the applications but the majority of leaves remained normal in appearance. There was a tendency for some of the ivy leaves to develop a yellowish or reddish colour resembling autumn coloration, in the second or third week after treatment.

Sodium Chlorate

Mode of Application: Spray, Sprinkle and Dry Salt. (Table 1. Exp. 8, Plots 1–3.)

Two pounds of sodium chlorate were applied to each of 3 plots, 1 square rod in area. The applications were made in the month of June for 2 successive years. The treatments, consisting of (1) a spray of 20% solution,

TABLE 1.—EXPERIMENTAL DETAILS AND RESULTS OBTAINED WITH APPLICATIONS OF SODIUM CHLORATE, SODIUM CHLORIDE, AND PETROLEUM OILS TO POISON IVY

Exp. no.	Plot no.	Plot size	Herbicide	Applications: Mode	When made	Amt. applied in first application	No. per year: 1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	No. yrs. made: Over-all	Follow-up	Total no.: Over-all	Follow-up	Total amt. herbicides used	Poison ivy cover (%): Before treatment	After treatment: At end of over-all application	At end of follow-up application	In summer of second year after last application
5	1	800 sq.ft.	Sodium chlorate	Spray	Mid June, late July, early Sept	4 gal. 10%	2	3	3	2	F*	F*	—	4	2	10	3	24 lb.	90	1	0.5	1
6	1	300 sq.ft.	Sodium chlorate	Spray	ditto	2 gal. 10%	3	F	F	F	F	—	—	1	4	3	6	7 lb.	95	1	0	0.25
8	1	1 sq. rod	Sodium chlorate	Sprinkle	June	2 gal. 10%	1	1	F	F	F	F	F	2	5	2	5	4 lb.	75	3	0.25	0.25
	2	1 sq. rod	Sodium chlorate	Spray	June	1 gal. 20%	1	1	F	—	—	—	—	2	1	2	1	3.5 lb.	75	1	0	0
	3	1 sq. rod	Sodium chlorate	Dry salt	June	2 lb.	1	1	—	F	F	F	F	2	4	2	4	5 lb	75	2	0.5	0.25
	5	1 sq. rod	Sodium chlorate	Spray	June and late July	1 gal. 10%	2	F	F	F	F	—	—	1	4	2	7	3 lb.	95	1	0.25	0.5
9	11	1 sq. rod	Sodium chlorate	Spray	June	1 gal. 10%	1	1	1	1	1	1	1	7	—	7	—	6.25 lb.	90	3	—	5
	8	1 sq. rod	Sodium chlorate	Spray	July	1 gal. 10%	1	1	1	1	1	1	1	7	—	7	—	6 lb.	80	1	—	3
	9	1 sq. rod	Sodium chlorate	Spray	Early Aug.	1 gal. 10%	1	1	1	1	1	1	1	7	—	7	—	7 lb.	90	35	—	60
	10	1 sq. rod	Sodium chlorate	Spray	Early Sept.	1 gal. 10%	1	1	—	1	1	1	—	5	—	5	—	5 lb.	85	70	—	70
12	1	1 sq. rod	Sodium chlorate	Dry salt	Nov. 6	0.5 lb.	1	—	—	—	—	—	—	1	—	1	—	0.5 lb	80	75	—	75
	2	1 sq. rod	Sodium chlorate	Dry salt	Nov. 6	1 lb.	1	—	—	—	—	—	—	1	—	1	—	1 lb.	80	75	—	65
	3	1 sq. rod	Sodium chlorate	Dry salt	Nov. 6	1.5 lb.	1	—	—	—	—	—	—	1	—	1	—	1.5 lb.	80	70	—	50
	4	1 sq. rod	Sodium chlorate	Dry salt	Nov. 6	2 lb.	1	—	—	—	—	—	—	1	—	1	—	2 lb.	80	60	—	50
12	5	1 sq. rod	Sodium chlorate	Dry salt	Nov. 6	3 lb.	1	—	—	—	—	—	—	1	—	1	—	3 lb.	80	20	—	25

TABLE 1.—EXPERIMENTAL DETAILS AND RESULTS OBTAINED WITH APPLICATIONS OF SODIUM CHLORATE, SODIUM CHLORIDE, AND PETROLEUM OILS TO POISON IVY—*Concluded*

Exp. no.	Plot no.	Plot size	Herbicide	Applications														Total amt. herbicides used	Poison ivy cover (%)			
				Mode	When made	Amt. applied in first application	No. per year							No. yrs. made		Total no.			Before treatment	After treatment		
							1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	Over-all	Follow-up	Over-all	Follow-up			At end of over-all application	At end of follow-up application	In summer of second year after last application
12	6	1 sq. rod	Sodium chlorate	Dry salt	Nov. 6	5 lb.	1	—	—	—	—	—	—	1	—	1	—	5 lb.	80	10	—	10
8	4	1 sq. rod	Sodium chloride	Spray	Mid June, late July, early Sept.	1 gal. 30%	3	2	2	4	3	—	—	5	—	14	—	42 lb.	85	13	—	60
	7	1 sq. rod	Sodium chloride	Sprinkle	ditto	2 gal. 30%	3	2	2	4	3	—	—	5	—	14	—	84 lb.	85	3	—	10
10	14	1 sq rod	Sodium chloride	Dry salt	June 20	10 lb.	1	—	—	—	—	—	—	1	—	1	—	10 lb.	75	75	—	75
	13	1 sq. rod	Sodium chloride	Dry salt	June 20	20 lb.	1	—	—	—	—	—	—	1	—	1	—	20 lb.	75	75	—	75
	12	1 sq. rod	Sodium chloride	Dry salt	June 20	40 lb.	1	—	—	—	—	—	—	1	—	1	—	40 lb.	70	20	—	35
	15	1 sq. rod	Sodium chloride	Dry salt	June 20	60 lb.	1	—	—	—	—	—	—	1	—	1	—	60 lb.	50	15	—	25
11	1	1 sq. rod	Sodium chloride	Dry salt	Oct. 7	20 lb.	1	—	—	—	—	—	—	1	—	1	—	20 lb.	85	85	—	85
	2	1 sq. rod	Sodium chloride	Dry salt	Oct. 7	40 lb.	1	—	—	—	—	—	—	1	—	1	—	40 lb.	85	85	—	85
	3	1 sq. rod	Sodium chloride	Dry salt	Oct. 7	60 lb.	1	—	—	—	—	—	—	1	—	1	—	60 lb.	85	85	—	85
	4	1 sq. rod	Sodium chloride	Dry salt	Oct. 7	80 lb	1	—	—	—	—	—	—	1	—	1	—	80 lb.	85	85	—	85
	5	1 sq. rod	Sodium chloride	Dry salt	Oct. 7	100 lb.	1	—	—	—	—	—	—	1	—	1	—	100 lb.	85	85	—	85
8	6	1 sq rod	Fuel oil	Sprinkle	Late June, early Sept.	2 gal.	2	2	2	2	3	—	—	5	—	11	—	21 gal.	85	3	—	8
13	1	½ sq. rod	Kerosene	Spray	June and July	1 gal.	2	—	—	—	—	—	-	1	—	2	—	2 gal.	90	65	—	90
	2	½ sq. rod	Kerosene	Spray	June	1 gal.	1	—	—	—	—	—	—	1	—	1	—	1 gal.	90	75	—	90
14	1	¼ sq. rod	Kerosene	Spray	June	1 gal.	1	—	—	—	—	—	—	1	—	1	—	1 gal.	85	80	—	85

(2) a sprinkle of 10% solution, and (3) a dry salt broadcast, reduced a stand of poison ivy from 75% to 1, 3, and 2% respectively. The spray application gave the best control but its advantage in reduction of the ivy present, over the other two methods, was not great. However, it was found that the follow-up treatment was more difficult and more prolonged on the plots treated with the sprinkling can or the dry salt, and as a result a larger amount of herbicide was required for complete eradication. It was difficult to secure a complete coverage with the sprinkling can on this size of plot. The large drops rolled off the leaves making it impossible to determine definitely which part of the plot had been treated, and consequently small areas were missed in the first application. Following treatment with the sprinkling can, the leaves turned brown in colour, became dry, curled, and crisp in a similar manner to those sprayed. With the dry salt applications the action of the herbicide on the poison ivy leaves was much slower. When applied as a solution to the foliage the leaves were usually dead within 5 to 7 days whereas, when the dry salt was applied to the ground, considerable green ivy foliage was present throughout the remainder of the summer.

Dry Sodium Chlorate Applications in Late Fall. (Table 1. Exp. 12, Plots 1–6.)

Single applications of from ½ to 5 pounds of sodium chlorate to plots of 1 square rod, made in November, yielded results in proportion to the amount of herbicide applied. Amounts up to 2 pounds decreased the poison ivy cover slightly but did not give satisfactory eradication. Applications of 3 and 5 pounds gave a fair control reducing the 80% stand to 20% and 10% respectively. These fall treatments had an adverse effect on the grass. Even the lightest application (½ pound per square rod) killed almost all of the grass present. As a result the plots were infested with such weeds as *Melilotus alba* Desr., *Nepeta Cataria* L., and *Chenopodium hybridum* L. in the summer following treatment. Previous to the treatment, grass was plentiful and there were only scattered plants of the above mentioned weeds present. In comparison, the June application of dry sodium chlorate, described under Mode of Application, was not nearly so severe on the grass.

Concentration of Spray Solution. (Table 1. Exp. 8, Plots 2 and 5.)

A comparison of the effect of concentration of sodium chlorate spray was obtained by making applications in June of 1 gallon of 10% and 20% solution, respectively, to plots of 1 square rod in area. By late August the plot receiving the 10% solution had a 35% cover of green poison ivy, which had developed since the herbicide was applied. It was given a second application at this time. As a result, less than 1% ivy was still present the following spring and only follow-up treatments were required. The plot receiving the 20% solution had a 10% cover present in late August, but was not given a second application. By the following June, there was only 2% ivy cover so less than ½ gallon of spray was required for this second treatment. Therefore, in this experiment, when 1 gallon was sprayed on 1 square rod, a rather light application, there was little difference between one treatment per year of 20% solution or two treatments per year of 10% solution.

Time of Year to Treat with Single Application. (Table 1. Exp. 9, Plots 8–11.)

One application per year for 7 successive years of 1 gallon 10% sodium chlorate sprayed on square rod plots in the months of (1) June, (2) mid July, (3) early August, and (4) early September, reduced a stand of poison ivy from an average 85% cover to 3, 1, 35, and 70% respectively. The September treatment, made when many of the poison ivy leaves had fallen and the remainder had assumed their reddish or yellow fall colouring, had no noticeable effect on the stand of poison ivy. This was so evident that discontinuance of this treatment was decided upon in the 3rd year, and no application was made. Further treatments made in the 4th, 5th, and 6th years confirmed this conclusion. The treatments made during the first week in August did not reduce the stand of poison ivy sufficiently to give a satisfactory control. The June and July applications reduced the stand of poison ivy gradually (see Table 2) until, at the end of the 7th year, only a few small scattered clumps remained. Although the July

TABLE 2.—EFFECTS OF SODIUM CHLORATE SPRAY ON POISON IVY*

Month of treatment	Percentage cover of poison ivy at time of treatments, and in the month of July for two years following treatment								
	Year of treatment							Year following treatment	
	1	2	3	4	5	6	7	1	2
June	90	30	45	25	8	7	5	3	5
Mid July	80	70	25	25	10	5	4	1	3
Early August	90	85	60	50	40	40	40	35	60

* Percentage cover of poison ivy on square rod plots receiving 1 application per year for 7 successive years of 1 gallon of 10% sodium chlorate sprayed on the foliage during (1) June, (2) mid July, and (3) early August.

treatment gave a somewhat better control than that made in June, it is not considered that this difference was due to time of treatment. The plot sprayed in June was in close proximity to a railroad with the result that a part of the plot was cut each year about the time application was made. Most of the ivy that was present at the conclusion of this experiment was concentrated on this part of the plot. From this experiment it is evident that if only 1 application can be made a year best results will be obtained from treatment made in June or early July. The experiment investigating concentration of spray solution suggests that fewer applications would have been required if a larger amount of herbicide had been used than 1 pound per square rod.

Spray. (Table 1. Exp. 6.)

The results obtained in the following experiment, when sodium chlorate solution was sprayed on poison ivy foliage, are representative for all the plots receiving this type of treatment. The area consisted of 300 square feet of dense poison ivy (95% cover). The ground was quite rough with a brush heap in the central area and a loose pile of stones to one side. Both of

these were completely overgrown with poison ivy. On the back or eastern portion of the plot, in the vicinity of a large stump, the ivy stems were much larger, higher, and not so numerous as on the front section. All applications were made using a knapsack sprayer with 10% solution of sodium chlorate. Details of treatments and the results obtained were as follows.

1936

June 5. The 95% stand of poison ivy was sprayed with 2 gallons of solution (Plate I, Figure 2).

June 12. The majority of the poison ivy leaves were dry, curled and brownish in colour. Where the ivy was thickest, however, some of the lowermost leaves were still normal in appearance and green in colour. At this time, these normal leaves were sprayed with one gallon of solution.

June 25. The poison ivy leaves were all brown, curled and dead (Plate I, Figures 3 and 4). There was evidence of regrowth on the stone pile (Plate II, Figure 1).

July 27. Sufficient new growth had appeared to give a 60% stand of poison ivy (Plate II, Figure 2). Recovery was not uniform over the whole plot, however, being more marked in the vicinity of the brush and stone piles where the original plants were shorter with smaller upright stems (Plate II, Figures 3 and 4). The area was given a second overall application with 2 gallons of solution.

July 30. The leaves of the sprayed plants were dry, curled, light green in colour and dying.

Aug. 13. New growth poison ivy was re-appearing on part of the area.

Aug. 26. The area as a whole had a 5% cover of poison ivy. The plants present were concentrated in one-quarter of the plot and consisted of small isolated clumps (Plate III, Figures 1 and 2). The area was given its third application with 3/4 of a gallon of solution.

Sept. 14. The leaves of the poison ivy treated on August 26 were all dead. The area appeared free of poison ivy (Plate III, Figure 3) but close examination revealed a few very small clumps. Some were in areas not treated on August 26, so had appeared since that time.

1937

June 22. Only 8 small clumps of poison ivy (less than 1% coverage) were found (Plate III, Figure 4). These ivy plants were sprayed with sodium chlorate.

July 12. The 8 clumps of green poison ivy present at this time were sprayed with sodium chlorate. Some of these clumps had appeared since the June 22 treatment as they were in different parts of the area.

Sept. 2. The 10 small clumps of poison ivy present were sprayed with sodium chlorate.

June 28, 1938. One small clump of poison ivy was found. It was sprayed with sodium chlorate.

Aug. 8, 1939. The 3 small clumps of poison ivy that were present were sprayed with sodium chlorate.

FIGURE 1. The equipment used in eradication experiments with poison ivy. —The illustrations from Plate I, Figure 2, to Plate III, Figure 4 inclusive, give a photographic record of the eradication of poison ivy on plot 1, experiment 6, when sprayed with 10% sodium chlorate. (Further details given in text.) FIGURE 2. General view of a part of the plot taken on June 5, 1936, immediately before the first application of sodium chlorate spray. There was an estimated 95% cover of poison ivy. FIGURE 3. General view of the same plot on June 25, 1936, 20 days after the first application of spray. The poison ivy leaves were all brown, curled, and dead. FIGURE 4. Close-up view of dead poison ivy plants on June 25, 1936, 20 days after the first application of spray. The dead leaves as well as the previous year's fruit still attached to the old stalks.

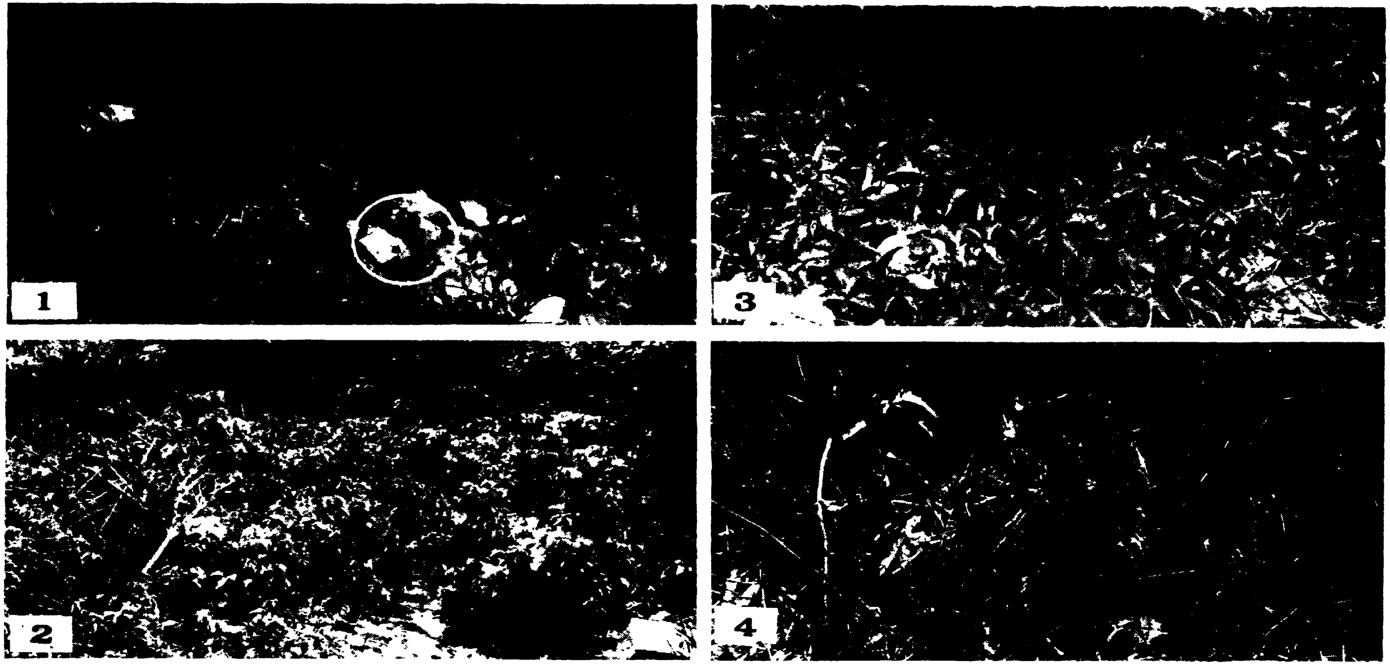

FIGURE 1. There was evidence of recovery on June 25, 1936, 20 days after the first application as can be seen by the new green leaves circled in the foreground. FIGURE 2. General view of the plot on July 27, 1936, 52 days after the first application and at the time of the second treatment. A 60% cover of poison ivy leaves had been produced since the first application. FIGURE 3. Close-up view on July 27, 1936, of the central portion of the plot showing the area in which the new green leaves were the thickest. FIGURE 4. The recovery of the poison ivy was not uniform over the whole plot however, as shown by this close-up view on July 27, 1936, of the back portion of the plot. A large number of dead stalks were visible but only 1 new green shoot. There was very little recovery of poison ivy on this part of the plot.

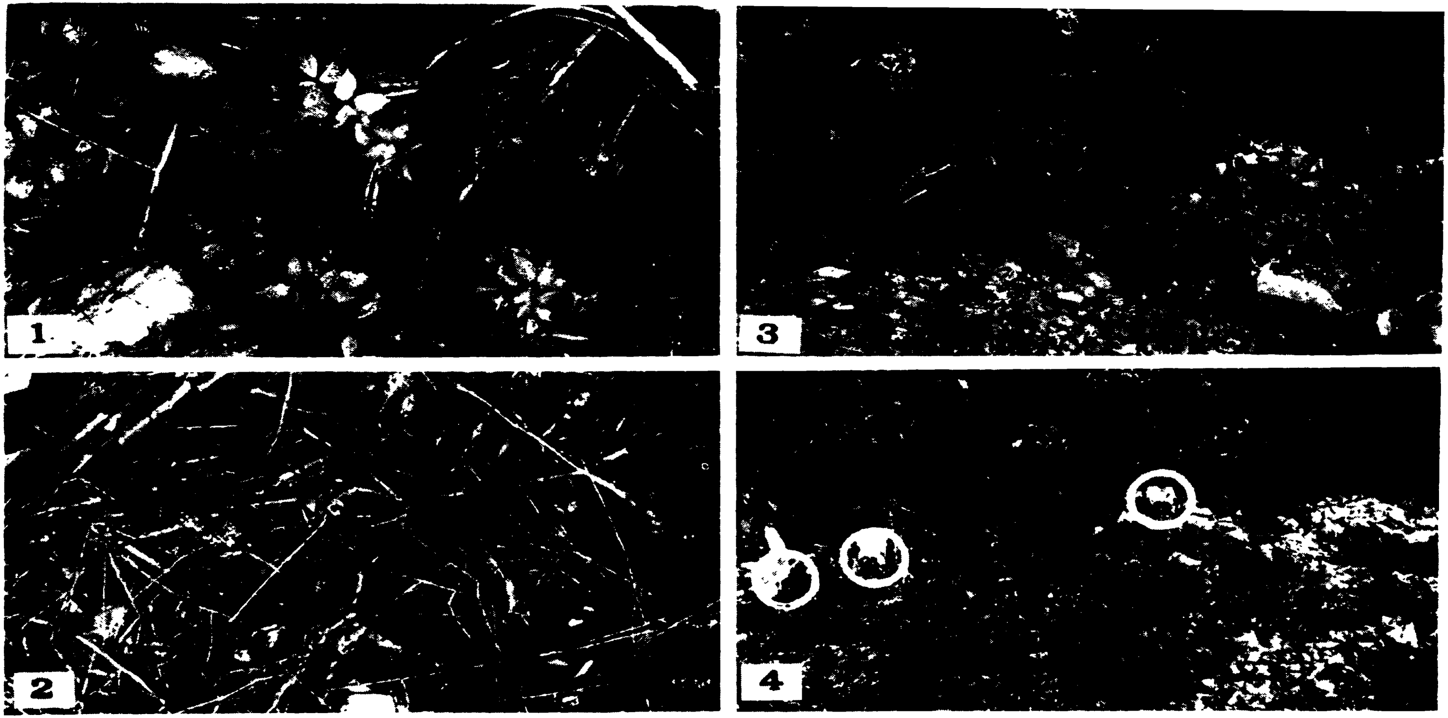

FIGURE 1. Close-up view of the central part of the plot on August 24, 1936, 4 weeks after the second spray and at the time of the third application. The 5% cover of poison ivy consisted of small scattered clumps concentrated on approximately one-quarter of the plot. FIGURE 2. Close-up view of the back portion of the plot on August 24, 1936, 4 weeks after the second application. No new green poison ivy leaves were to be found on this portion of the plot. FIGURE 3. General view of the plot on September 30, 1936, 5 weeks after the third application of spray. There was less than 1% cover of poison ivy with the plants so small and scattered that they cannot be seen in the photograph. FIGURE 4. General view of plot on June 15, 1937, the summer following the three applications of sodium chlorate spray. Three small clumps of poison ivy were visible on this part of the plot.

July 12, 1940. Two clumps of poison ivy were present. They were sprayed with sodium chlorate.

June 12, 1941. No poison ivy was found on the area.

Aug. 24, 1945. Three isolated clumps of poison ivy were present on the plot, each consisting of 2 or 3 upright stems. Therefore, a complete eradication was not obtained from the 5 years of spray treatments.

DISCUSSION

While poison ivy no doubt can be killed with persistent and continued use of common salt (sodium chloride) or furnace fuel oil, the results obtained in these experiments were far from impressive. In no case was a complete eradication obtained. With applications of dry common salt, large quantities must be used and in applications of solution to the foliage by means of sprayer or sprinkling can, oft-repeated treatments are required. Under conditions of these experiments, with shallow soil over limestone substratum, a better and more economical control was obtained with sodium chlorate. Dense stands of poison ivy were reduced to from 1 to 3% cover in one year with the chlorate herbicide. As a follow-up treatment, however, in eradicating these small scattered clumps, spraying the foliage with sodium chlorate was not satisfactory. At least 3 or 4 years of treatment were required and in some cases, 5 years did not completely remove them. The poison ivy leaves were killed by each application of spray but apparently the roots survived and put forth new growth, since many of the clumps kept re-appearing each year. Willard (23), in discussing the killing effect of chlorate sprays, states that destruction of the plant depends on getting a killing concentration of chlorate in the soil around the poison ivy roots. Pavlychenko (17), while investigating the herbicidal action of sodium chlorate on Canada thistle, could not find any evidence that chemicals in solution of herbicidal concentration are transported from the leaves to the root system. He considered that destruction of underground parts of perennial weeds was due to "producing a durable sterility of the top soil". Therefore, the application of an excess amount of dry sodium chlorate around the base of the stems or digging out bodily the few remaining clumps of poison ivy would no doubt have yielded better results than the continued spraying of the foliage.

SUMMARY AND CONCLUSIONS

1. Sodium chlorate, sodium chloride, furnace fuel oil, and a water white kerosene were investigated as herbicides for the eradication of poison ivy. Methods of treatment included application of solution to the foliage by means of a knapsack sprayer or sprinkling can, and dry salt broadcast by hand.

2. Poison ivy can be eradicated with sodium chlorate if treatment is persistent and thorough.

3. Common salt and furnace fuel oil are not considered satisfactory herbicides for the eradication of poison ivy. Because of repeated applications, large quantities were required even to reduce a dense stand to a light infestation. This resulted in greater expense and more labour than with chlorates.

4. Water white kerosene when applied as a spray to the foliage, proved of no value in eradicating poison ivy.

5. Three applications of 10% sodium chlorate solution, sprayed on the leaves at the rate of 1 gallon per square rod, with the first treatment made in June as soon as leaves are fully expanded, the second in late July, and the third in September, reduced dense stands of poison ivy to a few scattered plants.

6. Results obtained indicate that fewer overall applications of spray would be required during the year, if larger quantities of chlorate were applied than 1 pound per square rod.

7. Applications of sodium chlorate made as a solution with a sprinkling can or as the dry salt broadcast gave almost as good an initial kill as when sprayed on the leaves, but follow-up treatments were more difficult and larger quantities of herbicide were required to give equal results.

8. Spraying the foliage with sodium chlorate was not satisfactory as a follow-up treatment in eradicating the small scattered clumps of poison ivy that kept re-appearing in the years following the initial application.

9. With only 1 application a year, of 10% sodium chlorate solution sprayed on the leaves in June or early July at the rate of 1 gallon per square rod, 7 years of treatment were required to reduce a dense stand of poison ivy to a few scattered clumps. Similar applications in August or September had little or no effect on the poison ivy.

ACKNOWLEDGMENTS

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AN IMPROVED METHOD OF ROOTING ALFALFA CUTTINGS[1]

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Both in the testing for seed and forage yield and in breeding programs with alfalfa it is frequently necessary to propagate plants vegetatively. If the breeding system proposed by Kiesselback, Tysdal, and Westover (2) proves feasible, large numbers of cuttings will be required. An efficient technique of propagation is therefore of great importance.

The technique previously used at Saskatoon and probably fairly generally used elsewhere was to place sections with two nodes from fairly mature stems in sand and keep the sand moist. Only 1 or 2 leaves were usually left on the cuttings. At Saskatoon this technique has on the average given a low percentage of rooted cuttings. From some plants the rooting success was fairly high while other plants were almost impossible to propagate vegetatively by this method. As an average of a large proportion of plants not over 30 to 40% of the cuttings made would root.

Faced with the assignment of making a large number of cuttings in the spring of 1945, Mr. F. Rose, greenhouse foreman at the Dominion Forage Crops Laboratory, began experimenting with various procedures in the winter of 1944–45. From his studies a technique has been evolved which has been found to be very satisfactory. The procedure simply consists of standing stem sections in slowly running water. While the influence of such variable factors as air and water temperatures, light, etc., on the success of this method have not been critically studied, the high degree of success with fairly large populations under varying environmental conditions warrants publication of the method.

The equipment required consists of galvanized sheet iron troughs the dimensions of which may be varied to suit a variety of conditions. The ones used to date have been 4 or 5 feet long and 2 inches wide and 2 inches deep. One end of the trough is closed and into this end is fed a slowly flowing stream of water. The other end of the trough is left open and either the sheet iron in the bottom of the open end is raised about $\frac{1}{8}$ to $\frac{1}{4}$ inch or that end of the trough is set up on a thin block in order to maintain the water at a level of about $\frac{1}{8}$ to $\frac{1}{4}$ inch. Near the top along each side of the trough a row of holes about $\frac{1}{8}$ inch in diameter and about $1\frac{1}{2}$ inch apart is drilled. A second row of holes is drilled about $\frac{3}{4}$ inch below and slightly offset from the top row. Through these holes pieces of galvanized wire are inserted. A loop on one end of these wires and a slight bend in the other end holds them in place and yet permits their withdrawal when desired. These wires serve as supports to hold the stem cuttings upright and also serve to separate cuttings from different plants. By providing a multiple lead in for the water a battery of troughs may be operated at one time.

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The temperature of the water used at Saskatoon has been around 60° F. While it is probable that water temperature would influence both the success and rapidity of rooting, this has not been studied as yet.

Around 50 cuttings may be placed in a 1.5 inch section of the 2 × 2 inch trough. In order to provide for aeration and for light penetration the practice has been to leave alternative sections of the trough blank when as many as 40 or 50 cuttings were placed in a section. This practice may or may not be of importance but good results have followed its use.

Sanitation in the troughs is obviously important. After a batch is removed from a trough it is advisable to scrub it out thoroughly and to use a mild disinfectant. The problem of sanitation has been found to be much more serious in wooden troughs and for this reason their use is not recommended.

Stem sections need only to consist of one node and an internode. Thus more cuttings can be obtained than in the case of the moist sand technique where sections consisting of 2 nodes are used. The stems are cut just above the nodes and the lowermost cut surface is inserted in the water in the trough. It has been observed that fairly mature healthy vigourous stems give a higher proportion of successful rooting than succulent young stems. The statement by Garner (1) that "cuttings should be rich in stored food (carbohydrates)" may be the explanation of the above observation. Fully mature stems which have shed at least some of their leaves should be avoided if possible. It has been observed that there is a positive correlation between the abundance of healthy leaves on the cuttings and the vigour and rapidity of rooting. In this connection Garner (1) states that "leaves on stem cuttings are a definite advantage, their absence may preclude rooting".

The majority of cuttings in running water will send out roots in from 10 to 15 days. The roots generally develop from the cut surface, although occasionally when the cut end is diseased or injured they will be initiated a short distance up on the cutting. In contrast, with the moist sand technique a portion of the lower end of the cutting usually dies and the roots emerge from higher up on the cutting. This results in slower rooting. Practically as soon as the roots appear the practice has been to place the cuttings in soil. When the roots are allowed to develop in the water to more than $\frac{1}{8}$ to $\frac{1}{4}$ inch in length it becomes more difficult to plant them in soil without injury. Experience has shown that there is a very low mortality in transferring from the water directly to the soil. There is thus no need of using a moist sand culture as an intermediate step.

While no extensive comparisons have been made with the formerly used moist sand culture a limited study was conducted. Four mature plants were selected and 4 stem sections from each plant were placed in each of moist sand and running water. Alternative sections from a stem were placed in the two media. The results are recorded in Table 1.

The success of rooting in moist sand as shown in Table 1 is fairly typical of past extensive experience. The superiority of the running water technique in this small test is very pronounced and as will be shown later the degree of success in this test if anything was low compared to more extensive experience. The results in the above test are illustrated in Figure 1.

TABLE 1.—COMPARATIVE ROOTING OF STEM SECTIONS FROM FOUR PLANTS IN RUNNING WATER AND IN MOIST SAND

Plant designation	Running water		Moist sand	
	No. of cuttings made	No. of cuttings rooted	No. of cuttings made	No. of cuttings rooted
A	5	4	5	1
B	5	3	5	0
C	5	5	5	0
D	5	5	5	0
Total	20	17	20	1

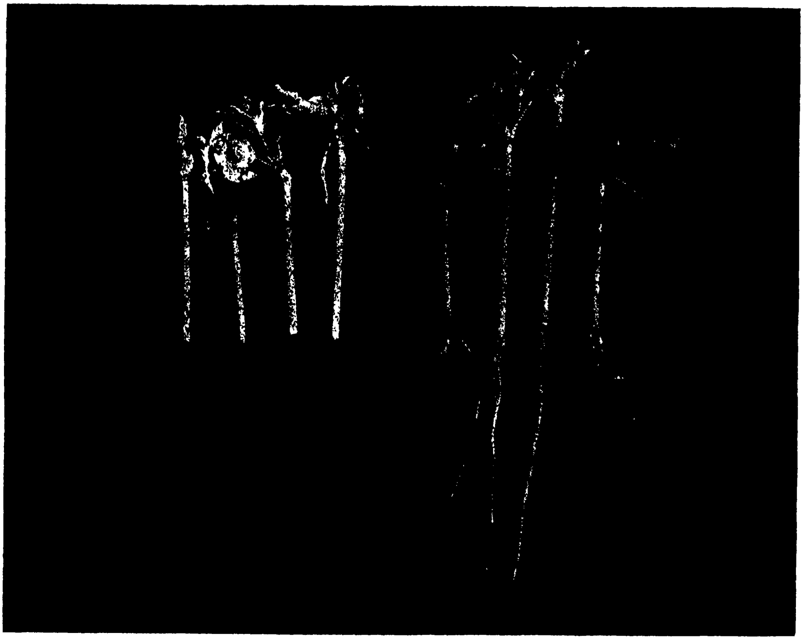

FIGURE 1. Comparative rooting 19 days after making cuttings from Plant C of Table 1. On left four sections kept in moist sand and on right four kept in running water. Note that leaves on sections in sand are practically all dead while those from running water are practically all living.

Fairly extensive use was made of the running water technique in the spring of 1945. From March 29 to April 2 there were 2043 cuttings made from 23 different plants of which 1835 or 89.8% rooted in from 11 to 17 days. Evidence of the influence of stage of development and vigour of the plant on successful rooting is indicated by the fact that of 657 cuttings made from 7 plants which were fairly mature and vigourous 637, or 97%, rooted, whereas from 10 plants which were noticeably weaker only 755 rooted cuttings, or 88%, were obtained from 854 attempted.

ACKNOWLEDGMENTS

Development of the technique described above is very largely due to the ingenuity and initiative of Mr. F. Rose and the author gratefully acknowledges his very valuable contribution.

SUMMARY

1. A method of rooting stem sections of alfalfa in running water is described.

2. Using mature stems, cuttings are made consisting of one node and the internode.

3. The cuttings are placed upright in slowly running cool water in galvanized iron troughs which are separated into sections with galvanized iron wire.

4. The size of the troughs used were 4 feet long, 2 inches wide, and 2 inches deep although this may be varied to suit convenience.

5. Rooting occurred on 85 to 97% of cuttings placed in running water compared to a maximum of 30 to 40% previously obtained in moist sand.

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CORRELATED INHERITANCE OF STEM RUST REACTION, NITROGEN CONTENT OF GRAIN AND KERNEL WEIGHT IN A BARLEY CROSS[1]

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The objective of the present barley breeding program in The University of Manitoba is the production of a stem rust resistant, smooth awned variety with good malting quality. In order to facilitate the breeding procedure, it is necessary to understand the mode of inheritance and the inter-relationship of the characters involved.

Criteria of malting quality were studied rather than actual malting quality characteristics for several reasons. The criteria studied, namely barley nitrogen content and kernel weight, are used by the plant breeders to eliminate undesirable hybrids in early generations after the cross. The determination of these criteria requires a much smaller sample of grain and much less time and equipment than actual malting tests.

As nitrogen content and kernel weight are indicators of malting quality, their relationship to stem rust resistance is important in a breeding program the object of which is stem rust resistant malting barley.

If nitrogen content and kernel weight are genetically independent of the factor or factors for stem rust reaction, no difficulty should be encountered in obtaining the desired combinations of the above quality factors with stem rust resistance. However, from examination of the malting data on many stem rust resistant hybrids, it appears the above combination is difficult to obtain.

REVIEW OF LITERATURE

Studies involving the inheritance of stem rust reaction in barley have been few.

Shands (10) reported in 1939 that Chevron (C.I. 1111) was selected and named at Chico, California in 1918 from seed originally obtained at the Swiss Seed Experimental Station, Zurich, Switzerland. Peatland (C.I. 5267) was selected from part of the same original lot at the Minnesota Agricultural Experimental Station in 1916.

Shands (10) found Chevron resistant to stem rust (*Puccinia graminis tritici*, Eriks. and Henn.) under severe epidemics in 1935 and 1937. In 1937 it showed an average of 1% stem rust. The resistance of Chevron was shown to be dominant and due to a single factor in crosses with Wisconsin Pedigree 38, Velvet and two smooth awned hybrids ×152 and ×169. A cross of Oderbrucker × Chevron gave the same result.

Mains and Martini (7) found Chevron to be highly resistant to three physiologic races of mildew (*Erysiphe graminis hordei*, March) and highly susceptible to leaf rust (*Puccinia anomola*, Rostr.). Tidd (12) showed it to be highly resistant to races 6 and 7 of barley mildew.

[1] A thesis submitted to the Committee on Graduate Studies at The University of Manitoba in partial fulfilment of the requirements for the Degree of Master of Science.

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Immer *et al.* (6) found Chevron resistant to 18 races and susceptible to one race of stem rust in the seedling stage. They also found that seedling reaction could be used as a test for adult plant reaction.

Power and Hines (8), in a Peatland × Glabron cross, found resistance to stem rust dominant and due to a single factor pair Tt. The factors for stem rust reaction and barbing of the awns were not linked. Reid (9) obtained a similar result in a cross of Barbless and Peatland.

Brookins (3) working with Peatland, located the factor pair Tt for stem rust reaction in the seventh linkage group. He found that seedling reaction to races 19, 39 and 56 was monohybrid with resistance dominant. The same factor pair controlled mature plant reaction to a large number of physiologic races.

Shands (11) in a study to determine what constituted an adequate sample for 1,000 kernel weight, found 400 kernels to be sufficient for accuracy.

Anderson *et al.* (1) demonstrated that within varieties there is a negative correlation between total barley nitrogen and malt extract, and a positive correlation between total barley nitrogen and each of the characters diastatic activity, malt loss, wort nitrogen, proteolytic activity, and starch liquefying power, in the malt. The simple correlations between total barley nitrogen and wort nitrogen, malt extract, diastatic activity, and proteolytic activity were significant beyond the 1% point. They also found that kernel weight, within varieties, was significantly and positively correlated with hours to steep and malt extract. Kernel weight, within varieties, was significantly and inversely correlated with wort nitrogen, and starch liquefying activity.

Anderson *et al.* (2) pointed out that the barley variety O.A.C. 21 is the most suitable variety in Canada for malting purposes. In the descriptions given by them with reference to malting quality, O.A.C. 21 is described as having a medium sized kernel and medium nitrogen content over a wide range of environmental conditions. Its malt extract, diastatic activity, and wort nitrogen are high. Little loss in extract occurs during malting. It produces a mellow well modified malt with a maximum of extractives.

In the same paper, Chevron is faulted on account of a very high nitrogen content, very low kernel weight, and percentage heavy grade barley. These faults result in low extract although enzymatic activity is good.

Peatland, a sister selection of Chevron, appears to be better than Chevron, but not equal to O.A.C. 21 in either kernel or malt characters.

MATERIAL AND METHODS

O.A.C. 21 was selected as the susceptible parent because it is the standard of quality for six-row malting barley in Canada. It is a good yielding, rough-awned, six-row, blue aleurone variety.

For the resistant parent there were two alternatives, Chevron or Peatland. Chevron was chosen because it is poorer in quality than Peatland, especially in the two quality factors being studied. It was thought that the greater the contrast between the parents, the more chance there would be of obtaining clear-cut information. Chevron is generally low in yield. It is a rough-awned, six-row, white aleurone variety.

The cross O.A.C. 21 × Chevron was made in the field in 1941. An F_1 population was produced in the greenhouse during the following winter. At the same time a backcross was made to the recessive parent. (O.A.C. 21 was known to be the recessive parent from observations on previous crosses of the same nature.) The material available for field planting in 1942 was as follows; 25 F_0 seeds, 29 backcross seeds, and seed from 20 F_1 plants grown in the greenhouse. The above along with both parents were subjected to an artificial epidemic of a large number of races of stem rust.

In the fall, all of the plants were pulled and taken inside for stem rust readings. A total of 592 F_2 plants were obtained. After rust readings were made 200 F_2 plants were selected at random to produce an F_3 population.

The seed of each of the 200 plants was divided into two lots. Twenty-five kernels, taken at random from each plant, were placed in one lot to be used for determination of stem rust reaction and genotype of the line. The remaining seed of each F_2 plant comprised the lot for use in the quality studies.

In 1943 the lot chosen for determination of rust reaction was subjected to an artificial epidemic of stem rust in the field. The other lot, for quality studies, was planted at another location. Each line was planted in a single row and at 10-row intervals the parents were planted. The planting for quality determinations was dusted with sulphur to prevent infection by stem rust. In this way the rust resistant and susceptible genotypes, which could be identified from their counterparts in the artificially infected plot, could be studied and compared as regards their quality factors without having the latter influenced and the comparison disturbed by the presence or absence of rust.

Stem rust readings for all material were made on a percentage basis (Clark *et al.*, 4). The percentage interval was 10. Among the F_3 lines those showing zero or trace on all plants were classified as resistant. The lines showing more than 10% on all plants were rated as susceptible. Those showing both resistant and suceptible plants were classified as segregating.

Thousand kernel weight was determined by counting 500 kernels at random from each F_3 line.

Duplicate nitrogen determinations on an oven dry basis were made by the Grain Research Laboratory, Winnipeg, for each F_3 line.

Statistical methods used were as described by Goulden (5).

RESULTS AND DISCUSSION

1. Inheritance of Stem Rust Reaction

Table 1 reveals that resistance to stem rust is dominant because all of the F_1 plants are resistant. The resistant hybrids, however, appear to be less resistant than the resistant parent. Chevron, the resistant parent, had 61.1% of its plants in the trace group (the remaining 38.9% in the zero group), while in the F_1, 94.7% were in the trace group. In the backcross resistant class, 100% were in the trace group, and in the F_2 resistant class 87.7% were in the trace group. The higher percentages of plants in the trace group in the hybrid offspring suggest that one or more modifying

factors are present. This slightly influences the progeny towards susceptibility. However, the modifying factor or factors do not have enough influence to take any plant out of the resistant class or to be of practical significance.

TABLE 1.—STEM RUST REACTION OF THE PARENTS, F_1, BACKCROSS AND THE F_2 IN THE CROSS O.A.C. 21 × CHEVRON

	Stem rust infection in per cent										Total
	0	t	10	20	30	40	50	60	70	80	
O.A.C. 21				1	4	9	6	9	3	1	33
Chevron	14	22									36
F_1	1	18									19
Backcross		14	1	1	1	3	3	1	1	1	26
F_2	53	368	14	18	38	36	32	21	9	3	592

In order to classify the F_2 offspring of the cross as resistant or susceptible to stem rust, the breeding behaviour of 194 F_2 plants was studied in the F_3. All of the plants, except 2, which showed zero or trace in the F_2 were either resistant or segregating in the F_3. The two lines that were neither resistant nor segregating showed 40% stem rust. The parent plants of these two lines probably escaped full infection in the F_2. It would appear, therefore, that in classifying all F_1, backcross and F_2 plants showing zero or trace as resistant, the error in classification is so small as to have no appreciable effect on the genetic ratios obtained. The plants that showed 20% or more rust in F_2 when grown in the F_3 all showed a heavy infection of rust. All backcross and F_2 plants that showed 20% or more rust can therefore be classified as susceptible.

The 15 plants showing 10% stem rust were grown for classification. The plant from the backcross was resistant. Of the 14 F_2 plants showing 10% rust 11 were resistant and three were susceptible.

TABLE 2.—SUMMARY OF STEM RUST REACTION OF THE PARENTS, F_1, BACKCROSS AND F_2 IN THE CROSS O.A.C. 21 × CHEVRON

	Resistant		Susceptible		Theor. ratio	Chi-Square	Probability
	Actual	Theor.	Actual	Theor.			
O.A.C. 21	0		33				
Chevron	36		0				
F_1	19		0				
Backcross	15	13	11	13	1 : 1	0 62	0.50 – 0.30
F_2	432	444	160	148	3 : 1	1.30	0.30 – 0.20

Table 2 shows the summarized and corrected classification of the data from Table 1. The fit of the actual to the theoretical ratios in the backcross and the F_2 population is respectively very good. This is especially true of the backcross where it is shown that a deviation from the 1 : 1 ratio, as great or greater than that found, would be expected by chance in from 30 to 50% of the cases. In the F_2 the corresponding deviation from the 3 : 1 ratio would be expected in from 20 to 30% of the cases.

Of the 194 F_3 lines grown, 46 were resistant, 94 segregated and 54 were susceptible. When these results were fitted to a 1 : 2 : 1 ratio, Chi-square was 0.79 with P between 0.70 and 0.50. This obviously is an excellent fit.

In view of the above results, it may be concluded that the inheritance of the degree of susceptibility and resistance to stem rust, exhibited respectively by O.A.C. 21 and Chevron, is governed by a single pair of factors with resistance dominant. Since Chevron and Peatland are sister selections, it seems reasonable to assume that they have identical genotypes for stem rust resistance. This factor has been designated as Tt by Powers and Hines (8). It was found by Brookins (3) to be in the seventh linkage group. If the factor is Tt then the genotype of O.A.C. 21 for stem rust reaction is tt and for Chevron TT.

Figures 1 and 2 show the amount of stem rust present in typical plants of the parents, F_1 and F_2.

2. Quality Studies

A. *Inheritance of Nitrogen Content*

In the F_3 generation of the cross, 187 of the 200 lines sown produced enough seed for quality determinations. The lines used for this purpose are those grown in the plot where stem rust infection was prevented. Nitrogen content was determined for each line as described previously. The stem rust reaction of the lines was known since a sample of each line was exposed to stem rust infection in a separate nursery. Thus, the genotype with regard to stem rust reaction, was known for each line.

Table 3.—Frequency distribution of nitrogen content in per cent for the parents and the different genotypes in the F_3

	Percentage nitrogen									
	2.145	2.245	2.345	2.445	2.545	2.645	2.745	2.845	2.945	3.045
O.A.C. 21	1	0	6	12	2					
Chevron		2	0	1	6	8	3	1		
Parent Totals	1	2	6	13	8	8	3	1		
F_3 Susc.	1	3	8	13	14	4	8	2	1	
F_3 Seg.		4	8	18	21	13	13	8	4	1
F_3 Resis.	1	1	2	5	12	12	5	1	3	1
F_3 Totals	2	8	18	36	47	29	26	11	8	2

The F_3 data presented in Table 3 indicate transgressive segregation for nitrogen content. When the combined distribution of the F_3 groups is compared to the combined distribution of the parents, 10 (or 5.35%) of the F_3 lines exceeded the parents in nitrogen content. It is interesting to note that the F_3 segregating group, as would be expected, has the complete range of nitrogen content (with the exception of the lowest class, in all probability missed due to chance) exhibited by the combined resistant and susceptible F_3 groups.

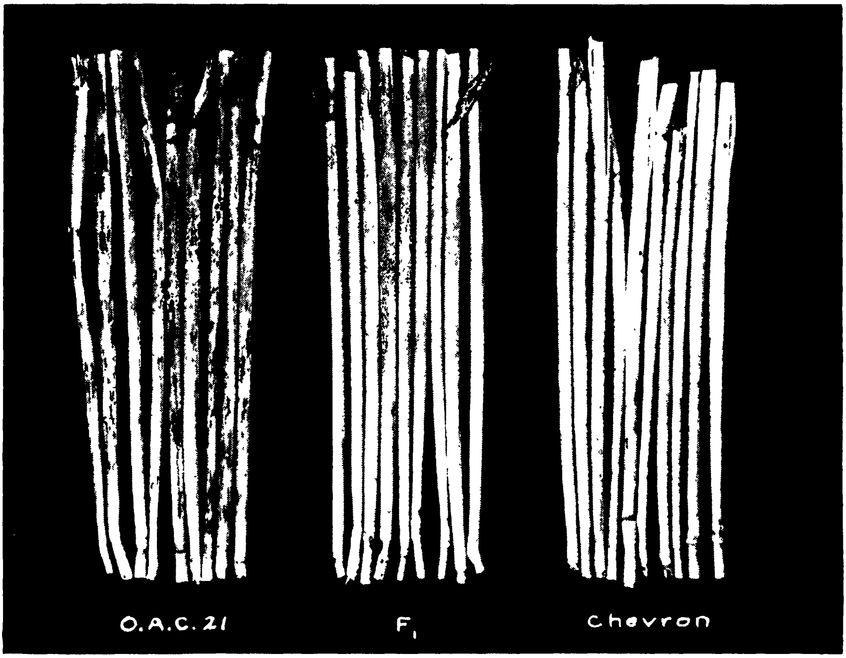

FIGURE 1. Stem rust infection on the parents and F_1.

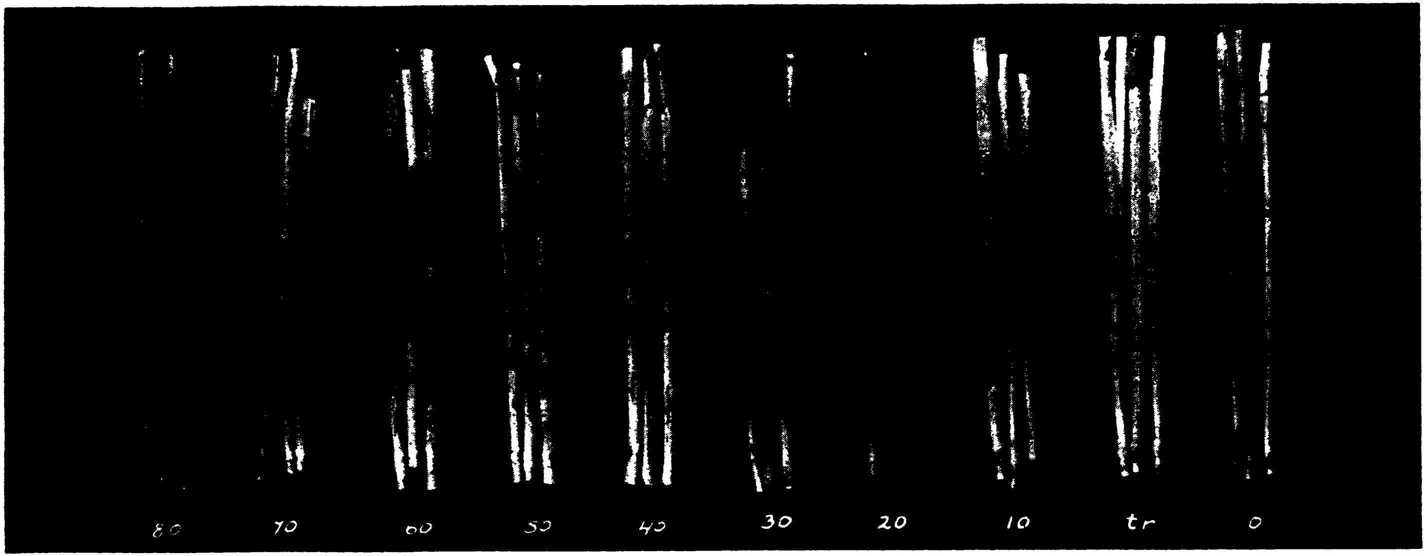

FIGURE 2. Range of stem rust infection on F_2 plants in per cent.

If transgressive segregation has occurred, lines lower in nitrogen content than the parents would be expected. However, results similar to these are obtained repeatedly in breeding programs when an attempt is made to increase or decrease a quantitative character if the maximum or minimum limit is being approached. A good example of this is yield. Two high yielding types are often crossed and the resulting progeny almost invariably have many lower yielding lines and very few or no higher yielding lines. The same can be said for nitrogen in the present study. Within the genetic limits represented by the parents involved, O.A.C. 21 is probably nearer the lower limit for nitrogen content than Chevron is near the upper limit. Consequently there is a tendency toward high nitrogen in the progeny of this cross.

In view of this definite tendency we would expect to have more F_3 lines with higher nitrogen content, in relation to the parents, than lines with lower nitrogen content. The population studied was small and as only 10 lines out of 187 exceeded the resistant parent in nitrogen content, it is understandable that no lines lower than the susceptible parent occurred in this population.

The F_3 totals for each nitrogen class were fitted to the theoretical normal frequency distribution. Table 4 presents the results. Chi-square was 6.06 and the P value at the 30% point was 6.06. This is a good fit and indicates that nitrogen content exhibits typical quantitative inheritance and is dependent on multiple factors.

TABLE 4.—THEORETICAL NORMAL FREQUENCIES AND ACTUAL FREQUENCIES FOR PER CENT NITROGEN IN THE F_3

Nitrogen class	Theoretical normal frequency	Actual frequency	Nitrogen class	Theoretical normal frequency	Actual frequency
2.145	2.61	2	2.645	37.70	29
2.245	8.14	8	2.745	26.46	26
2.345	19.02	18	2.845	13.82	11
2.445	31.13	36	2.945	5.38	8
2.545	39.98	47	3.045	1.54	2

B. *Inheritance of Kernel Weight*

Thousand kernel weight data were obtained on the same 187 F_3 lines as were used for nitrogen determinations. The data are presented in the same manner as for nitrogen content.

The distribution of thousand kernel weight for the parents and F_3 is given in Table. 5.

Transgressive segregation for kernel weight is indicated by the data presented in Table 5. When the combined distribution for the F_3 groups is compared to the combined distribution of the parents, eight (or 4.28%) of the F_3 lines fall below the parents and cover a range of four kernel weigh classes. Similarly two (or 1.07%) of the F_3 lines exceed the parents, but both lines are in the kernel weight class immediately above the limit of the parents. It is interesting to note that the range of the F_3 segregating group falls exactly between the ranges of the resistant and the susceptible groups.

TABLE 5.—FREQUENCY DISTRIBUTION OF THOUSAND KERNEL WEIGHT IN GRAMS FOR THE PARENTS AND DIFFERENT GENOTYPES IN THE F_3

	Thousand kernel weight (1000 KW) in grams													
	19.495	20.495	21.495	22.495	23.495	24.495	25.495	26.495	27.495	28.495	29.495	30.495	31.495	32.495
O.A.C. 21							1	2	3	6	5	3	1	
Chevron					2	6	8	4	1					
Parent totals					2	6	9	6	4	6	5	3	1	
F_3 Susc.					1	2	2	17	15	9	2	4	0	2
F_3 Seg.			1	2	0	10	23	23	21	7	2	1		
F_3 Resis.	1	1	1	2	5	10	13	6	4					
F_3 Totals	1	1	2	4	6	22	38	46	40	16	4	5	0	2

As indicated above, kernel weight tends to be lower in the progeny than in the parents just as nitrogen content tends to be higher in the progeny than in the parents. This tendency towards low kernel weight can perhaps be explained in the same manner as the tendency toward high nitrogen content. Here again, within the genetic limits of the parents of this cross O.A.C. 21, the susceptible parent, may be nearer to the upper limit for kernel weight than Chevron, the resistant parent, is to the lower limit. Thus, the chances of obtaining a lower kernel weight in relation to the parents, are greater than of obtaining a higher kernel weight.

The F_3 totals for each kernel weight class were fitted to the theoretical normal frequency distribution. The results are presented in Table 6. The Chi-square value was 10.74 with the P value between the 10% point (10.64) and the 5% point (12.59). This is again a satisfactory fit. The fit, however, is not as good as for nitrogen. The above result indicates that the inheritance of kernel weight is that of a typical quantitative character and is governed by multiple factors.

TABLE 6.—THEORETICAL NORMAL FREQUENCIES AND ACTUAL FREQUENCIES FOR 1000 K. W. IN THE F_3

1000 K.W. class	Theoretical normal frequency	Actual frequency	1000 K.W. class	Theoretical normal frequency	Actual frequency
19.495	.08	1	26.495	39.01	46
20.495	.33	1	27.495	35.40	40
21.495	1.50	2	28.495	18.53	16
22.495	4.95	4	29.495	10.27	4
23.495	12.55	6	30.495	3.75	5
24.495	24.11	22	31.495	1.09	0
25.495	35.15	38	32.495	.24	2

C. *Relationship of the Factors for Nitrogen Content and Kernel Weight to the Factor for Stem Rust Reaction*

This section is concerned with determining as far as possible, whether or not linkage exists between the factor for stem rust reaction and the factors governing nitrogen content and kernel weight. It is not concerned with the effect of stem rust infection on nitrogen content or kernel weight.

Both the simple and partial correlation coefficients are presented in Table 7.

TABLE 7.—SIMPLE AND PARTIAL CORRELATION COEFFICIENTS

Partial correlation \ Simple Correlation	Nitrogen content %	Stem rust reaction	1000 kernel weight
Nitrogen content %		−.1697*	−.2065‡
Stem rust reaction	−.0761		.5098‡
1000 kernel weight	−.2855‡	.6397‡	

‡ 1% level of significance attained.
* 5% level of significance attained.

In Table 7 the partial correlation coefficients were calculated with the item not involved held constant. The simple correlation coefficients are in the upper right hand corner and the partial correlation coefficients are in the lower left hand corner. In the following discussion of the correlation coefficients, it should be understood that in the frequency distribution the lowest class represents resistance to stem rust and the highest class susceptibility.

Table 7 reveals that the simple correlation coefficient between nitrogen content and stem rust reaction is negative and quite low. When kernel weight is held constant the partial correlation coefficient remains negative and becomes lower. In other words, as susceptibility to stem rust increases, nitrogen content decreases to a small extent. However, when the effect of kernel weight is removed the amount of decrease in nitrogen content becomes insignificant.

Both the simple and the partial correlation coefficients for kernel weight and stem rust reaction are positive and highly significant. This means that as susceptibility to stem rust increases kernel weight also increases. This is really quite evident on examination of the kernel weight distribution for the F_3 population in Table 5.

The simple correlation coefficient between nitrogen content and kernel weight is negative and significant at the 1% point. When the effect of stem rust reaction is held constant the partial correlation remains negative, becomes larger and is still significant at the 1% point. Therefore, as kernel weight increases nitrogen content decreases and vice versa.

In calculating the correlation coefficients numerical values differing by equal amounts were substituted for the stem rust reaction groups (resistant, segregating and susceptible). In view of the fact that the stem rust reaction groups are not actually numerical, combined frequency distributions were tested for independence and association by means of the Chi-square test. This was done to check the reliability of the correlation coefficients for nitrogen content and stem rust, and, kernel weight and stem rust. Following are Tables 8 and 9 used for above tests. Chi-square in both cases was corrected for continuity by the method developed by Yates (13) and described by Goulden (5).

TABLE 8.—COMBINED FREQUENCY TABLE FOR STEM RUST REACTION AND ARBITRARY NITROGEN CLASSES

Rust class		Nitrogen content in per cent						Totals
		2.20 2.39	2.40 2.49	2.50 2.59	2.60 2.69	2.70 2.79	2.80 3.09	
Resis.	actual theoretical	4 6.44	5 8.28	12 10.81	12 6.67	5 5.98	5 4.83	43
Seg.	actual theoretical	12 13.47	18 17.33	21 22.62	21 13.96	13 12.51	13 10.11	90
Susc.	actual theoretical	12 8.09	13 10.39	14 13.59	4 8.37	8 7.51	3 6.06	54
Totals		28	36	47	29	26	21	187

$x^2 = 10.54$ $P = .20(9.80) - .10(12.02)$

TABLE 9.—COMBINED FREQUENCY TABLE FOR STEM RUST REACTION AND ARBITRARY 1000 KERNEL WEIGHT CLASSES

Rust class		1000 Kernel weight					Total
		19.00 24.99	25.00 25.99	26.00 26.99	27.00 27.99	28.00 32.99	
Resis.	actual theoretical	20 8.28	13 8.74	6 10.50	4 9.20	0 6.21	43
Seg.	actual theoretical	13 17.33	23 18.29	23 22.14	21 19.25	10 12.99	90
Susc.	actual theoretical	3 10.40	2 10.97	17 13.28	15 11.55	17 7.80	54
Totals		36	38	46	40	27	187

$x^2 = 50.93$ $P = .01(16.81)$

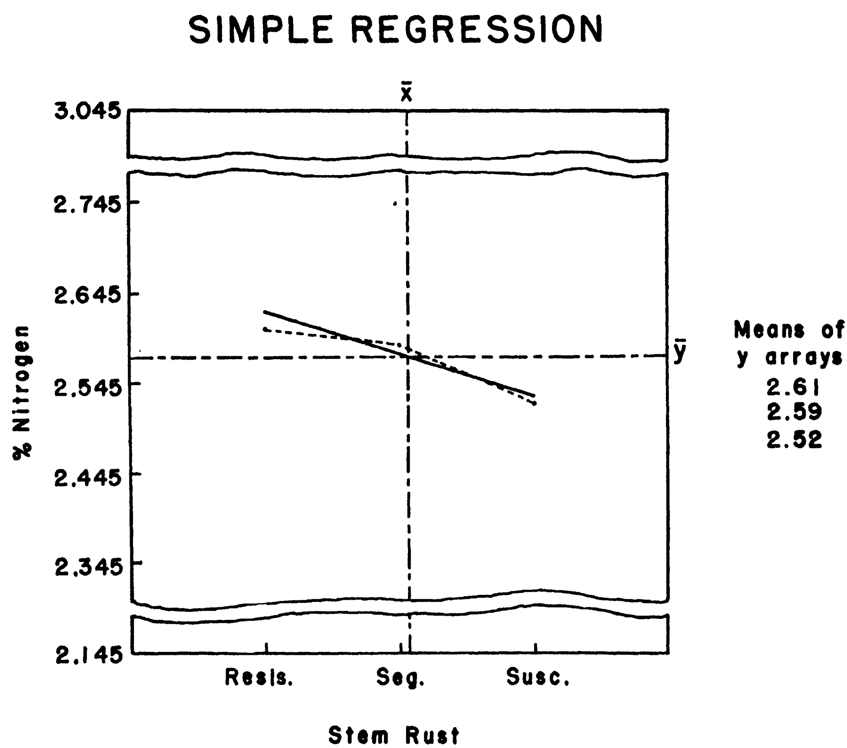

FIGURE 3. Simple regression graph for nitrogen content (%) on stem rust reaction.

In the case of nitrogen content and stem rust reaction there is no evidence of association as shown by Chi-square because in from 10 to 20% of the cases deviations such as obtained would be due to chance. This is the same general conclusion which may be arrived at from the correlation coefficient between these two characters.

With regard to kernel weight and stem rust reaction, there is good agreement between the results obtained by both the test for independence and association and the correlation coefficients. In this case both tests show a strong relationship between these two characters.

It has been shown earlier in this paper that stem rust reaction is governed by a single factor and nitrogen content and kernel weight are governed by multiple factors. We may therefore assume, in view of the above results, that a fairly large percentage of the factors governing kernel weight are linked with the factor for stem rust reaction. We may also assume that very few or none of the factors governing nitrogen content are linked with the factor for stem rust reaction. However, there is a correlation between nitrogen content and kernel weight. This is shown by the significant correlations in Table 7 and by Anderson *et al.* (1). Through this correlation and the association between kernel weight and stem rust reaction, nitrogen is indirectly affected to a small extent by the genotype of a plant for stem rust reaction.

In order to demonstrate graphically the interrelation of the factors for nitrogen content and stem rust, and, the factors for 1000 kernel weight and stem rust, regression lines were plotted. Following are the simple and partial regression coefficients.

——	Simple regression coefficient	Partial regression coefficient
Nitrogen content (%) on stem rust reaction	−.4262*	−.2185
1000 K.W. (grams) on stem rust reaction	1.3425‡	1.2872‡

‡ 1% level of significance attained.
* 5% level of significance attained.

The regression graphs for nitrogen on stem rust are shown in Figures 3 and 4. The simple regression line shows that as recessive genes for stem rust reaction increase, nitrogen content decreases slightly. However, when the effect of kernel weight is removed the regression line becomes almost flat and is insignificant.

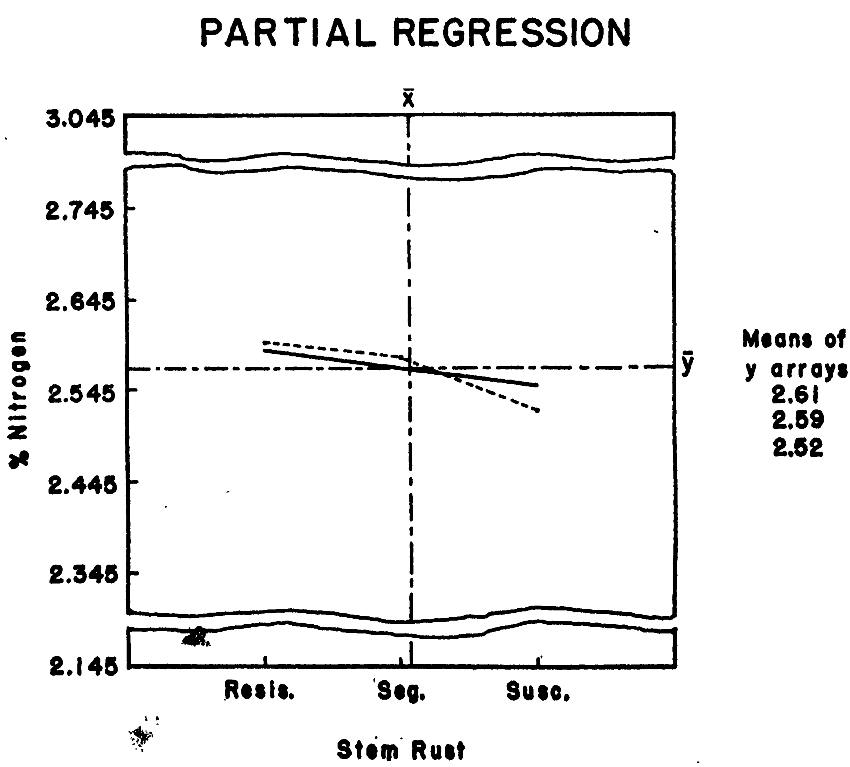

FIGURE 4. Partial regression graph for nitrogen content (%) on stem rust reaction.

The regression graphs for 1000 kernel weight on stem rust reaction are shown in Figures 5 and 6. The simple and partial regression lines are practically identical. In this case as recessive genes for stem rust reaction increase 1000 kernel weight increases. In other words as susceptibility to stem rust increases size of kernal increases. This is the reverse of the combination desirable for good quality rust resistant barley.

The close linkage between kernel weight and stem rust reaction has been broken. A rust resistant F_3 selection made (by the author) in 1943 from a bulk lot of the same cross was found to have high kernel weight. The 1000 kernel weight of the selection was 34.46 grams as compared to a weight of 34.16 for a comparable sample of O.A.C. 21.

SUMMARY AND CONCLUSIONS

In the cross O.A.C. 21 × Chevron, the inheritance of stem rust is governed by a single factor pair with resistance dominant. This factor is probably the same as that found in Peatland by Powers and Hines (8). There is evidence that one or more minor factors modify the reaction of the resistant offspring towards susceptibility. However, the effect of such modifying factors is of no practical significance.

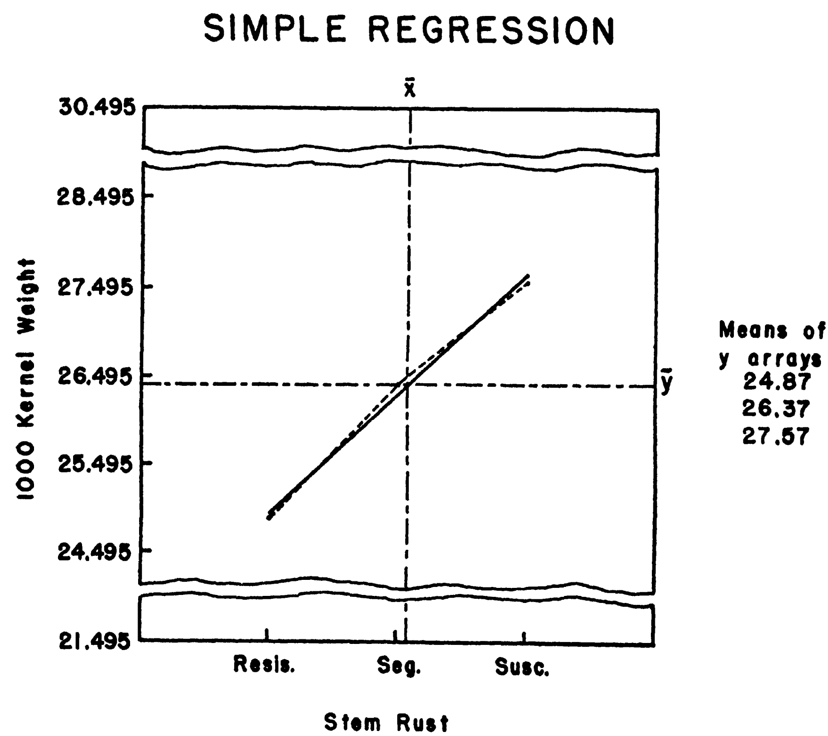

FIGURE 5. Simple regression graph for 1000 kernel weight (grams) on stem rust reaction.

The inheritance of nitrogen content in the same cross is governed by multiple factors. There is a definite tendency for nitrogen content in the F_3 progeny to be higher than that of the parents genetically comparable for the stem rust factor.

The inheritance of kernel weight is also governed by multiple factors. In this case, there is a definite tendency towards lower kernel weight in the F_3 progeny than in the parents genetically comparable for the stem rust factor.

None or few of the factors for nitrogen content are directly associated or linked with the factor for stem rust reaction. However, some of these factors are apparently associated with it indirectly through its relation to kernel weight. This indirect relationship results in a weak association of high nitrogen content with rust resistance.

A large proportion of the factors for 1000 kernel weight appear to be linked with the factor for stem rust reaction. This linkage is fairly close and results in rust resistance being associated with low kernel weight. However, this linkage was broken when a much larger population was used.

In a breeding program with the objective of producing stem rust resistant barley with good malting quality, using Chevron or possibly Peatland as the source of rust resistance, it would be advisable to grow much larger populations than would be necessary if no linkage existed between kernel weight and the stem rust factor.

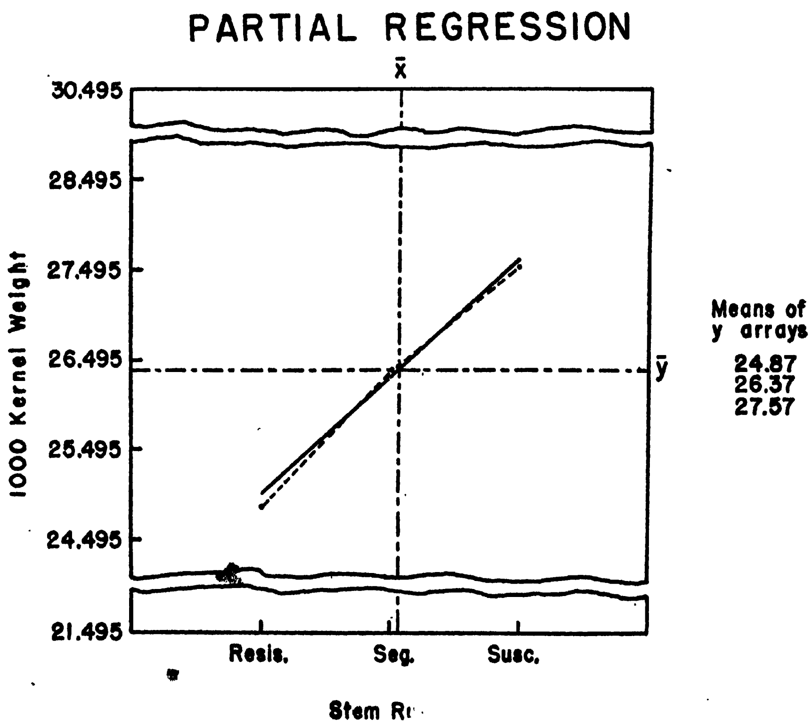

FIGURE 6. Partial regression graph for 1000-kernel weight (grams) on stem rust reaction.

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L'IMPORTANCE DES PÂTURAGES NATURELS DANS QUÉBEC[1]

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Ministère de l'Agriculture, Québec

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Le "Relevé écologique des herbages du Québec", projet du Ministère provincial de l'agriculture, fut inauguré en 1940 avec la collaboration de la Station expérimentale fédérale de Ste-Anne de la Pocatière. En 1941, le Collège Macdonald y apportait son concours, après avoir conduit d'autres enquêtes sur les pâturages des Cantons de l'Est. Ce projet de recherches nous a permis d'accumuler de nombreux renseignements sur les gazons naturels[3] du Québec; sur leur nature, leur diversité, leur valeur agronomique et leur répartition géographique.

Dans Québec, comme dans tout pays agricole où l'industrie laitière est à l'honneur, les gazons naturels sont très abondants. La Nature les fait naître spontanément et les propage partout où la forêt fait place à l'agriculture et où la charrue n'a pas, depuis quelques années, bouleversé le sol arable. La Nature accomplit ce travail selon des lois biologiques que nous voudrions mieux connues chez-nous; elle distribue ces gazons d'une façon assez capricieuse et complexe, offrant à notre Province un manteau végétal d'herbages spontanés, aux nuances botaniques des plus diversifiées, où le facteur climat, le sol et l'histoire agronomique des champs se complaisent à exercer une influence souvent complexe.

Les résultats du "Relevé écologique des herbages" nous révèlent à date le partage géographique suivant entre les principales espèces graminöides qui poussent spontanément (i.e. sans ensemencement préalable) dans la Province: l'agrostide coloniale (*A. tenuis*) se cantonne plutôt dans le Bas St-Laurent, dans l'Est du Québec, ainsi qu'aux fortes altitudes des Cantons de l'Est; la fétuque rouge traçante (*F. rubra* var. *genuina*), plus généralisée que l'espèce précédente, se partage un vaste domaine qui va, apparemment, de la Gaspésie à St-Hyacinthe et de Huntingdon aux Cantons de l'Est inclusivement, avec au moins des traces importantes dans le district de l'Assomption; l'agrostide commune (*A. alba* L.) se trouve partout dans le Québec, et semble particulièrement abondante dans les Cantons de l'Est, tandis que le pâturin des prés (*P. pratensis* L.) assez répandu dans les comtés de Châteauguay, Huntingdon, Joliette et l'Assomption, devient prédominant dans la région d'Ottawa. Voilà des faits écologiques apparemment dus au facteur climatique.

Quant à l'influence des conditions de sol, soulignons que l'agrostide palustre (*A. palustris* Buds.) abonde dans les habitats frais où le drainage externe est passablement défectueux, tandis que la danthonie à épi (*Dan-*

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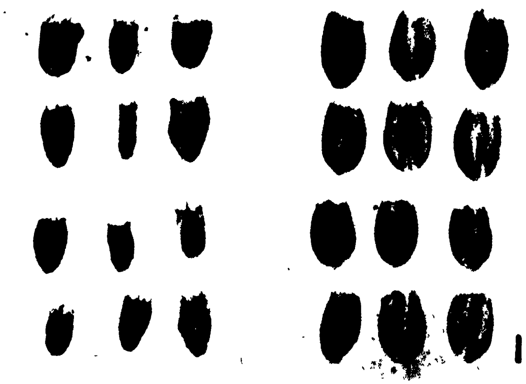
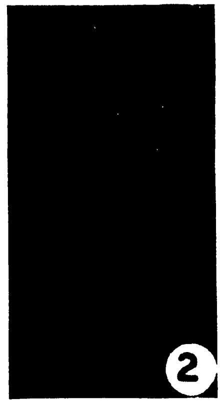
[1] Ce travail fut, en substance, présenté au Congrès annuel de l'ACFAS, le 11 Octobre 1943. Il est publié avec l'approbation du Prof. L. C. Raymond.

[2] Assistant, recherches herbagères provinciales.

[3] Au sens écologique du mot, le terme pâturages "naturels" est ici improprement employé. Nous le faisons, toutefois, en accord avec la terminologie du Comité provincial des pâturages et pour éviter la confusion dans la pratique. Au point de vue écologique, nous devrions plutôt dire pâturages semi-naturels, étant donné que nous traitons de la végétation herbacée qui dépend de la Nature et de l'intervention de l'homme. Quant au terme "naturel" il est réservé aux associations vétégales qui existent en dehors de l'influence humaine. (Voir A. G. Tansley. The British Islands and their Vegetation, p. 194, Cambridge University Press, 1939, p. 930.)





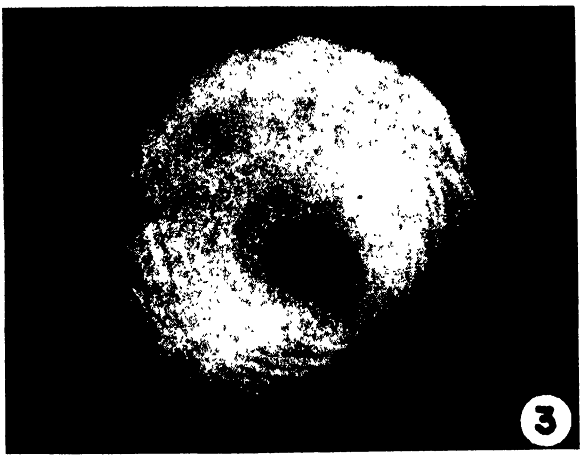


FIGURE 1. At left, 12 kernels from a head of Thatcher wheat that was severely attacked by bacterial black chaff. At right, 12 kernels from a healthy head. ×2.

FIGURE 2. Photomicrograph of a Congo Red smear preparation made from a lesioned glume of wheat. ×1500.

FIGURE 3. A colony of *Xanthomonas translucens* growing on beef peptone agar, photographed by oblique transmitted light. ×10.

FIGURE 4. The drop agglutination test. At left, agglutination following suspension of *Xanthomonas translucens* in the immune serum diluted to 1 part in 39 of phenolated saline. At right, no agglutination following suspension of *X. translucens* in phenolated saline. If a species of bacteria other than *X. translucens* had been suspended both drops would have the appearance of the drop on the right. Note that the few clumps remaining in the saline suspension due to incomplete dispersion of the bacterial mass are readily distinguishable from true agglutination. True agglutination, as shown in the drop at left, results in the clearing of the liquid. ×2½.

thonia spicata) et les épervières Piloselle et orangée semblent tolérer facilement les sols secs, pauvres et acides. Le pâturin des prés affectionne les endroits exceptionnellement enrichis de fumier animal, ainsi que les terres nouvellement défrichées. Enfin l'agrostide commune, répondant au facteur agronomique, compte parmi les premiers envahisseurs dans les prairies vieillissantes ou dans les jeunes pâturages; et la danthonie semble hériter surtout des terres franches et légères, longtemps soumises à une agriculture abusive.

Les résultats du Relevé écologique, accumulés à date, nous laissent donc apercevoir quelques grands traits de la carte des herbages naturels que nous espérons pouvoir dresser complètement d'ici quelques années[4]. Une telle carte ne semble pas devoir être une expression complète des conditions de notre milieu édapho-climatique, mais, à notre humble avis, elle sera tout de même un bon reflet des conditions dominantes de nos habitats agronomiques. Elle ajoute une note vivante aux grandes lignes cartographiques des sols. C'est vraiment une appréciation partielle de notre milieu. Cette signification écologique n'est pas à dédaigner dans l'organisation de notre future agriculture d'herbages que nous devons, à l'instar des Etats-Unis, organiser chez-nous, agriculture d'herbages dont la vocation multiple en est une d'alimentation animale et de conservation des sols arables. En effet la culture rationnelle des herbages, bien comprise, constitue le meilleur moyen actuellement connu pour conserver économiquement cette ressource naturelle.

Tous les gazons naturels du Québec n'ont pas la même valeur agronomique et, d'une façon générale, leur productivité est inférieure à celle des gazons à court-terme. Ils sont destinés à perdre de leur importance, à l'avenir, selon l'intensification de notre agriculture. Déjà, à cause de leur production médiocre, une antipathie se dessine à leur sujet chez nos cultivateurs progressifs. Il n'en demeure pas moins vrai que leur contribution dans l'alimentation de notre cheptel bovin et ovin restera considérable dans certaines régions où la culture extensive conserve des avantages, ainsi que dans les paroisses de colonisation; ou bien encore dans les districts trop rocheux ou trop montagneux pour être cultivés.

L'importance de nos gazons naturels dépend encore de la possibilité de les améliorer par la fertilisation en surface. Cette possibilité varie avec la nature des gazons, ou des sols qui les déterminent. C'est ainsi que les sols secs, souvent couverts de danthonie ou de mousses (Politrichum), ou encore les sols sensibles à la sécheresse, ne se sont pas montrés favorables à la méthode d'amélioration susmentionnée. Dans ces habitats, la difficulté provient d'un manque d'humidité dans la couche superficielle du sol durant certaines périodes de la saison de végétation et sous certains climats, difficulté qui peut être surmontée à l'aide de plantes douées d'un système radiculaire bien développé en profondeur autant qu'en surface. Ce caractère morphologique est plus ou moins absent chez presque toutes les principales espèces graminoïdes de nos gazons naturels. Cette difficulté peut disparaître temporairement: ce fut le cas des argiles lourdes de la région de St-Hyacinthe durant l'été 1943, où la précipitation atmosphérique, plutôt très abondante, ne fut certainement pas normale.

[4] Ce projet provincial se poursuit depuis le printemps 1944 sous la direction du Prof. L. C. Raymond Collège Macdonald, P. Qué.

Par ailleurs, il y a des cas où les conditions d'humidité sont généralement très favorables durant toute la saison de végétation et où la seule fertilisation en surface ne donne cependant pas des résultats apparemment économiques. Cela dépend de l'état des vieux gazons. Voici deux exemples concrets, pris dans le Bas St-Laurent: l'un dominé par l'agrostide coloniale et l'autre par la fétuque rouge traçante. Dans ces deux cas il y a à la surface du vieux gazon un matelas plus ou moins épais de débris végétaux qui empêche le trèfle blanc sauvage de s'introduire et de se propager facilement. De tels résultats ne sont pas inévitables. Dans le cas de l'agrostide coloniale, le gazon est vieux et formé de touffes serrées les unes contre les autres, touffes que les animaux ne semble pas aimer. Il en résulte que les feuilles seules sont broutées; les gaines et une partie des tiges ainsi délaissées forment des touffes serrées constituant un matelas de débris végétal qui s'épaissit avec les années. Apparemment, en fertilisant adéquatement ces gazons, alors qu'ils sont encore jeunes et avant que le matelas ne se forme, on encouragerait tôt la propagation du trèfle blanc sauvage, et la paissance se ferait alors plus complète. Dans le deuxième cas, celui de la fétuque rouge, plante habituellement beaucoup plus goûtée des animaux, la paissance fut très légère et alors la végétation annuelle séchait et s'accumulait à la surface. Ce gazon, vieux d'une quinzaine d'années, est situé au trait-carré de la ferme. Il représente une exception, mais il sert, tout de même, à démontrer qu'un matelas épais de débris végétaux et accumulé à la surface du sol peut constituer, et constitue très souvent, un obstacle sérieux à l'amélioration économique des gazons naturels par la seule fertilisation en surface. Dans les sols cultivables, il faut détruire, bouleverser ces gazons pour les améliorer rapidement.

La valeur agronomique de nos gazons naturels dans l'agriculture du Quebec dépend aussi de leur utilité et de leur nécessité dans la protection des sols contre l'érosion. Il arrive que les terres ravinées, montagneuses, à pentes trop raides, sont sérieusement exposées à l'érosion si on en détruit la couverture végétale. Sir E. John Russell, directeur de la Station de Rothamsted, Angleterre, disait, dans un congrès scientifique, que l'érosion provient, dans la plupart des cas, d'une destruction de l'équilibre biologique entre le sol et sa couverture végétale. Beaucoup de régions québecoises fournissent des exemples de ces erreurs ou de ces dangers.

L'importance économique de ces gazons naturels est, par ailleurs, diminuée lorsqu'ils entrent en compétition avec un autre gazon, ensemensé celui-là, et plus désirable au point de vue productivité et valeur nutritive, et que l'on voudrait maintenir plus longtemps. Mais ces gazons naturels, mieux adaptés à l'habitat de paissance que ces derniers, et plus agressifs, ont souvent trop vite raison de leurs compétiteurs ensemencés. Cette valeur négative des gazons naturels peut s'accentuer, si les méthodes culturales font défaut dans la préparation adéquate du terrain dans lequel le semis le plus désirable doit être ensemencé; c'est-à-dire, si on a laissé trop de vigueur au gazon spontané. C'est ce qui arrive avec certains vieux gazons naturels (d'agrostide coloniale ou de fétuque rouge) qu'on ne laboure qu'une fois pour les semer en céréales, avant de les retourner en foin ou en pacage.

RÉSUMÉ

Si les gazons naturels sont très abondants dans Québec, leur valeur agronomique se mesure à leur productivité, à leurs qualités nutritives; elle varie aussi en fonction de leur "améliorabilité" par la fertilisation appliquée en surface, et de leur utilité contre les menaces de l'érosion. Cependant leur agressivité, en certains cas, est un obstacle à l'amélioration générale de nos herbages.

SUMMARY

Natural swards are very abundant in Quebec pastures. Their agronomic value depends on their productivity and nutritive value, on their potential improvement by top dressings and their usefulness against soil erosion. They are, however, aggressive, and this is often a drawback in the general betterment of our grasslands, especially with short-term pastures where taller and productive pasture species are concerned.

THE REACTION OF BARLEY VARIETIES TO WHEAT STEM SAWFLY ATTACK[1]

C. W. FARSTAD[2] AND A. W. PLATT[3]

[Received for publication March 22, 1946]

The status of barley as a host plant of the wheat stem sawfly (*Cephus cinctus* Nort.) is not well established. Ainslie (1) in his list of host plants states that sawflies attack *Hordeum jubatum* and suggests that cultivated barley "should probably" be added to his host plant list.

Criddle (4, 5, 6, 7) refers to barley as being subject to some sawfly infestation. He points out that this crop is normally seeded late and thus escapes serious injury. There are frequent references to severe initial infestations but no published information on the resulting damage from such attack. In correspondence with headquarters, November 9, 1930, Mr. Criddle discussed barley as follows: "The insect (*Cephus cinctus* Nort.) oviposits freely in common wheat, spring rye, winter rye, durum wheat, emmer, barley and oats. In the first two the sawfly survives and multiplies; in all other grains it finds difficulty in maintaining itself." However, there is no mention of which variety or varieties were under observation but it might be assumed to be Trebi barley, since that variety was commonly grown in Manitoba at that time.

No other published references on the reaction of barley to sawfly damage have been found. The general opinion appeared to be that barley was at least somewhat susceptible to sawfly damage, for as late as 1941 late seeding of barley was recommended in order to avoid sawfly losses (8). Thomson (11) in 1938 and Champlin and Marshall (2) in 1940 published results of experiments in which much higher yields of barley were obtained by early seeding. As a result of publicity given to this work growers rapidly changed over from late seeding of barley to early seeding. If barley were susceptible to sawfly damage this change in seeding practice would result in important economic losses where this insect was prevalent.

Accordingly a series of field observations was begun on sawfly infestation and damage to early-seeded barley, followed by some experiments on varietal differences in reaction to infestation and damage. This paper summarizes the observations made and the experiments conducted, and these are discussed in relation to the sawfly problem.

FIELD OBSERVATIONS

The sawfly infestation in Apex and Thatcher wheat and Prospect barley under comparable conditions was noted at the Swift Current Station in 1941. All plots were in the late boot and early heading stage of development, which is the ideal stage for maximum oviposition. All stems of both wheat varieties were infested with an average of 4 eggs per stem, while only 3% of the Prospect barley stems were infested with an average of 1 egg per stem. In a second series of replicated, comparable plots of Marquis wheat, Prolific spring rye, Prospect barley and Banner oats, the

[1] A joint contribution of the Division of Entomology, Science Service, and the Cereal Division, Experimental Farms Service, Dominion of Canada Department of Agriculture. Contribution No. 2416 of the Division of Entomology. Contribution No. 137, Cereal Division, Experimental Farms Service.

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rye and wheat were infested 100%, while the oats and barley had infestations of 36 and 40%, respectively. In addition, a number of farmers' fields were examined. In several instances they had seeded strips of Prospect barley on the margins of the wheat fields as traps. In all cases the infestation in the traps was substantially lower than in the wheat crop, this in spite of the fact that the sawflies had to pass through the barley before reaching the wheat and that the stage of development of the barley crop was apparently such that oviposition could readily take place. Sample counts of infestation in the barley and wheat at Blumenhof, Saskatchewan, were 40 and 90% and at Tugaske, Saskatchewan, 25 and 83%, respectively.

At Craigmyle, Alberta, Newal barley was grown in a field severely infested by sawfly. The initial infestation was over 90%, but there was practically 100% larval mortality and no apparent damage in the field.

In 1943 a considerable acreage of Prospect barley was grown in the immediate vicinity of Swift Current, Saskatchewan, in fields severely infested with sawfly. As no wheat was growing in many of these large fields, there was little choice of host plants during the flight period and subsequent initial infestations approached 100%. However, damage to these crops was negligible. Actual counts indicated less than 1% cutting in barley as compared with 80 to 90% in wheat in the same district. Detailed stem examinations revealed that a large proportion of the larvae had died during the period immediately following the hatching of the eggs. Of the few that had fed rather extensively within the stem, less than 5% completed their development and cut the stem.

These observations indicated that while barley might be infested with sawfly to a considerable extent under some conditions, it was highly resistant to sawfly cutting. However, that same fall reports of severe cutting of barley were received from widely scattered points in Saskatchewan and Alberta. Investigations of fields at Rosetown, Plenty and Instow, Saskatchewan, and at Brant, Alberta, revealed that cutting to the extent of approximately 50% had occurred in each case. At Instow the variety grown was O.A.C. 21 and at all the other points it was Hannchen. Collections of the stubble from Brant and Instow for observations on emergence of sawfly adults were made in the spring of 1944. The larvae were active and appeared to be normal in all respects. Subsequent emergence compared favourably with that from wheat. From the Hannchen field at Brant the sexes emerged in approximately equal numbers but from the O.A.C. 21 at Instow there was a preponderance of females.

VARIETAL TESTS

These field observations strongly suggested that varietal differences as to the degree of sawfly damage existed in barley. Information on such differences might be expected to elucidate the position of barley as a host plant for sawfly and to be of considerable economic significance. Accordingly a small series of varietal tests was conducted, the results of which are presented below.

MATERIALS AND METHODS

Nine varieties were chosen for study. These were Hannchen and O.A.C. 21, which appeared to have some susceptibility; Newal and Prospect, which had shown evidence of some resistance; Plush and Rex, recommended

for production in some areas where sawflies were prevalent; Regal and Trebi, varieties formerly grown to a considerable extent in the sawfly area; and Titan, a new variety of considerable promise in this area.

In 1944, test plots were located at Brant, Alberta, and at Swift Current and Shaunavon, Saskatchewan. The nine varieties were grown in single 10-foot rows, replicated three times and arranged as randomized blocks. They were grown on summer-fallow adjacent to infested wheat stubble and the general plan of the tests was similar to that described for wheat (9). At Brant grasshoppers and rodents destroyed the test. At the other two points the percentage of stems infested, the percentage cut and the percentage of larvae parasitized by *Microbracon cephi* Gahan were noted. The percentage of infested stems was arrived at by splitting 20 culms from each plot and noting whether or not they contained eggs or larvae. The presence of either resulted in the stem being classed as infested. To determine the percentage cut, 50 culms were examined in each plot after the crop had matured and the number severed by sawflies noted. It was found that estimates of damage similar to those described for wheat (9) were difficult to make because the barley straw tended to break up after maturity, and only by direct examination could differentiation between sawfly damage and natural breaking be made.

In 1945, tests were located at Nobleford, Alberta, and at Scott, Regina, Shaunavon and Swift Current, Saskatchewan. The same varieties were grown and the general plan of the tests was the same as in 1944 except that 5 replicates were used instead of 3. In addition, 3 nurseries were grown at Swift Current, using 3 dates of seeding, namely, May 1, 10 and 19. The replicates of the three nurseries were randomized over the plot area. The fifth replicate of the late-seeded nursery was discarded because of rodent injury. The percentage infestation was taken on the Nobleford and Swift Current nurseries only and the percentage cutting on all nurseries, both in the same manner as in 1944.

In both years these nurseries were located adjacent to similar nurseries of wheat, and thus it was possible to make a reasonably accurate comparison of the reaction of these two crops to sawfly damage. The design of the nurseries did not allow, however, for a precise statistical comparison.

In analyzing the data from the barley nurseries the following procedure was used. Where data on the percentage of infested stems had been taken, these were transformed to $\mathrm{Sin}^2\,\theta$ and analyzed by variance. The data on percentage of cut stems at Swift Current in 1945 were similarly treated. Those on percentage cut from the other nurseries were transformed to $\sqrt{x + \frac{1}{2}}$ and analyzed in the same manner. These transformations appear to be the most suitable for these data according to the discussion of Cochran (3).

In addition to the above tests the percentage of stems cut by sawflies was noted in each of the varieties grown in the barley yield tests at Swift Current in 1945. These varieties were grown in 3 rod-row plots replicated six times.

Results

A summary of the data obtained on infestation is presented in Table 1. In Table 2 the varieties are classified for infestation, using Trebi as the

TABLE 1.—PERCENTAGE OF CULMS OF BARLEY VARIETIES INFESTED WITH WHEAT STEM SAWFLY IN VARIOUS NURSERIES, 1944–1945

Variety	C.A.N.	Percentage infested						
		Swift Current				Shaunavon	Nobleford	Averag
		1944	1945*	1945†	1945‡	1944	1945	
Trebi	753	58.3	50.0	63.3	60.0	46.6	43.6	53.6
Plush	1,117	55.0	72.0	83.3	67.5	86.6	60.6	70.8
Prospect	1,140	76.6	70.0	83.3	87.5	50.0	18.4	64.3
Newal	1,089	78.0	86.4	80.0	75.0	76.6	56.0	75.3
Titan	1,164	60.0	90.0	80.0	82.5	60.0	49.6	70.4
O.A.C. 21	734	65.0	86.0	96.7	100.0	60.0	42.8	75.1
Regal	742	56.6	92.0	66.7	75.0	86.6	51.0	71.3
Rex	1,113	90.0	98.0	93.3	95.0	73.3	81.4	88.5
Hannchen	837	95.0	98.0	100.0	97.5	100.0	92.8	97.2
Average	—	70.5	82.5	83.0	82.2	71.1	55.1	74.0

* Seeded May 1. † Seeded May 10. ‡ Seeded May 19.

TABLE 2.—CLASSIFICATION OF BARLEY VARIETIES BASED ON PERCENTAGE INFESTED, USING TREBI AS THE STANDARD AND THE RESPECTIVE "NECESSARY DIFFERENCES" AS UNITS

Variety	Swift Current				Shaunavon	Nobleford
	1944	1945*	1945†	1945‡	1944	1945
Plush	0	0	0	0	+1	0
Prospect	0	0	0	+1	0	+1
Newal	0	+1	0	0	0	0
Titan	0	+2	0	+1	0	0
O.A.C. 21	0	+1	+1	+2	0	0
Regal	0	+2	0	0	+1	0
Rex	+1	+2	+1	+1	0	+1
Hannchen	+1	+2	+1	+1	+2	+2

* Seeded May 1. † Seeded May 10. ‡ Seeded May 19.

standard and the necessary differences as units. The necessary differences were calculated by multiplying the standard errors of the mean difference by the value of t at the 5% point. The means, standard errors, F values, etc., are given in Table 3. Significant varietal differences were obtained in all tests. Trebi was the most resistant to infestation, Hannchen and Rex the most susceptible. The differences among the other varieties were not great.

Table 4 is a summary of the data on cutting by sawfly, and in Table 5 the varieties are classified for cutting, using Trebi as the standard and the necessary differences as units. Significant varietal differences were established in all tests but one. On the average, Trebi had the least cutting and in no individual test did any variety have significantly less. Hannchen suffered the greatest damage, having significantly more cutting than Trebi in all tests. Rex also showed considerable susceptibility. Plush, Prospect,

TABLE 3.—MEANS, STANDARD ERRORS, ETC., OF DATA ON PERCENTAGE INFESTATION AND CUTTING OF BARLEY VARIETIES EXPOSED TO SAWFLY ATTACK (DATA TRANSFORMED FROM PERCENTAGES TO $\sin^2 \theta$ OR $\sqrt{x + \frac{1}{2}}$ AS SHOWN)

Station	Year	Mean	S.E.	S.E. in per cent	N.D.	F	5 per cent point	Transformation used
Percentage Infested								
Swift Current	1944	58.7	4.97	8.5	14.9	5.00	2.59	$\sin^2 \theta$
	1945*	70.8	5.40	7.6	15.0	7.18	2.25	$\sin^2 \theta$
	1945†	69.6	6.20	8.9	18.6	3.88	2.59	$\sin^2 \theta$
	1945‡	69.5	6.13	8.8	17.9	4.96	2.36	$\sin^2 \theta$
Shaunavon	1944	61.2	7.58	12.4	22.7	3.76	2.59	$\sin^2 \theta$
Nobleford	1945	48.5	5.05	10.4	14.0	9.42	2.25	$\sin^2 \theta$
Percentage Cut								
Swift Current	1944	2.64	0.50	18.9	1.50	1.85	2.59	$\sqrt{x + \frac{1}{2}}$
	1945*	30.5	3.23	10.6	9.00	10.80	2.25	$\sin^2 \theta$
	1945†	24.7	4.55	18.4	12.6	3.22	2.25	$\sin^2 \theta$
	1945‡	21.3	4.25	20.0	12.4	5.07	2.36	$\sin^2 \theta$
Shaunavon	1944	1.08	0.29	26.8	0.87	6.60	2.59	$\sqrt{x + \frac{1}{2}}$
	1945	1.24	0.37	29.8	1.02	2.63	2.25	$\sqrt{x + \frac{1}{2}}$
Nobleford	1945	1.49	0.39	26.2	1.08	2.97	2.25	$\sqrt{x + \frac{1}{2}}$
Regina	1945	1.91	0.32	16.8	0.89	19.79	2.25	$\sqrt{x + \frac{1}{2}}$
Scott	1945	1.31	0.29	22.1	0.80	5.69	2.25	

* Seeded May 1. † Seeded May 10. ‡ Seeded May 19.

and Newal were quite resistant. The damage to Titan, on the average, was slightly greater than in Newal, but it was significantly higher than in Trebi in three tests whereas in Newal it was significantly higher in only one. It will be noted that the varieties tended to fall in the same order for both infestation and cutting.

A summary of the data on the parasitism sustained by the sawflies in the various varieties is presented in Table 6. In general, those varieties having the heaviest infestations had the greater percentage of the sawflies parasitized. It might be expected that the parasites would tend to concentrate where hosts were most numerous (10).

Data on the percentage cutting sustained by a few of the varieties in the rod-row test at Swift Current in 1945 are presented in Table 7. Average results on cutting from the seven nurseries are also presented. These data, though admittedly meagre, suggest that there are varieties which might be much more susceptible than any that were included in the nurseries.

Based on the average of all varieties in the dates-of-seeding tests at Swift Current in 1945, the three dates of seeding showed no appreciable difference in infestation (Table 1). Similar data for cutting show a lessening

TABLE 4.—PERCENTAGE OF CULMS OF BARLEY VARIETIES CUT BY WHEAT STEM SAWFLY IN VARIOUS NURSERIES, 1944–1945

Variety	Percentage cut									
	Swift Current				Shaunavon		Noble-ford	Regina	Scott	Average
	1944	1945*	1945†	1945‡	1944	1945	1945	1945	1945	
Trebi	5.0	8.8	4.0	1.0	0.0	0.0	0.0	0.0	0.0	2.1
Plush	1.7	16.8	15.2	5.0	0.0	0.0	2.2	0.8	0.8	4.7
Prospect	5.0	15.2	17.6	6.0	0.0	0.0	0.8	0.8	4.0	5.5
Newal	6.7	27.2	10.4	7.0	0.0	0.8	1.4	1.6	0.0	6.1
Titan	8.3	19.2	13.6	12.0	0.0	0.8	1.4	4.8	0.8	6.8
O.A.C. 21	10.0	23.2	24.8	20.0	1.7	3.2	1.6	0.0	0.0	9.4
Regal	8.3	38.4	15.2	29.0	0.0	1.6	3.0	5.6	1.6	11.4
Rex	6.7	48.0	36.0	26.0	1.7	3.2	6.0	8.8	4.8	15.7
Hannchen	15.0	53.6	40.8	31.0	8.3	6.8	8.2	25.6	6.4	21.7
Average	7.4	27.8	19.7	15.2	1.3	1.8	2.7	5.3	2.0	9.3

* Seeded May 1. † Seeded May 10. ‡ Seeded May 19.

TABLE 5.—CLASSIFICATION OF VARIETIES BASED ON PERCENTAGE CUT USING TREBI AS THE STANDARD AND THE "NECESSARY DIFFERENCES" AS UNITS

Variety	Swift Current			Shaunavon		Noble-ford	Regina	Scott
	1945*	1945†	1943‡	1944	1945	1945	1945	1945
Plush	+1	0	0	0	0	0	0	0
Prospect	0	+1	0	0	0	0	0	+1
Newal	+1	0	0	0	0	0	0	0
Titan	+1	0	+1	0	0	0	+1	0
O.A.C. 21	+1	+1	+1	0	+1	0	0	0
Regal	+2	0	+2	0	0	0	+1	0
Rex	+3	+1	+1	0	0	+1	+2	+1
Hannchen	+3	+2	+2	+2	+1	+1	+4	+2

* Seeded May 1. † Seeded May 10. ‡ Seeded May 19.

of damage as seeding was delayed (Table 4). However, owing to low spring temperatures that delayed development of the early-seeded grain and to an abnormally long sawfly flight period, no conclusions should be drawn from this experiment.

The infestation of susceptible wheat varieties in nurseries adjacent to the barley tests was, in all cases, in excess of 90%. Among the barleys only Hannchen equalled this figure but Rex approached it closely. The percentage cutting in Apex and Thatcher wheat was 80 and 75, respectively, whereas comparable figures for Rex and Hannchen were 16 and 22. Thus, in these tests wheat was much more susceptible than barley. The percentage of sawfly larvae parasitized in barley varieties varied from 6 to 51% (Table 6). In the adjacent wheat nurseries the percentage parasitism was less than 5% except in the case of one very late-maturing variety. No

TABLE 6.—PERCENTAGE OF WHEAT STEM SAWFLY LARVAE IN BARLEY VARIETIES PARASITIZED BY *Microbracon cephi* AT SWIFT CURRENT AND SHAUNAVON, SASKATCHEWAN, 1944

Variety	Percentage parasitized		
	Swift Current	Shaunavon	Average
Trebi	0	13	6
Plush	33	13	23
Prospect	14	12	13
Newal	28	10	19
Titan	8	18	13
O.A.C. 21	26	20	23
Regal	17	18	18
Rex	49	35	42
Hannchen	51	52	51

TABLE 7.—COMPARATIVE DAMAGE TO BARLEY VARIETIES BY WHEAT STEM SAWFLY IN NURSERIES AND VARIETAL TEST PLOTS AT SWIFT CURRENT

Variety	C.A.N.	Percentage cut	
		Average of 7 nurseries	Rod-row test
Trebi	753	2.1	0.0
Plush	1,117	4.7	0.0
Prospect	1,140	5.5	0.0
Newal	1,089	6.1	0.0
Titan	1,164	6.8	0.0
O.A.C. 21	734	9.4	0.0
Regal	742	11.4	0.0
Rex	1,113	15.7	1.0
Hannchen	837	21.7	—
Compana	1,154	—	2.5
Glacier	1,149	—	6.6
Beecher	1,153	—	9.3
Atlas	702	—	14.1
Bulk sel. C. I. 7008	—	—	15.8

explanation suggests itself as to why the parasites should concentrate in the barley when larger numbers of potential hosts were available in the wheats.

An examination of Table 4 reveals that the damage sustained by the barleys varied greatly from nursery to nursery. This would suggest that environmental factors markedly influence the degree of damage. The data are too meagre to attempt to postulate what these environmental factors might be and what effect they might have.

DISCUSSION

The results of the varietal tests show that differences in reaction to sawflies exist among barleys. These differences were, very largely, in agreement with previous field observations. Thus Newal and Prospect were observed to suffer little damage in the field and in the tests proved to be

quite resistant. Similarly, in all but one of the fields showing severe damage the variety was Hannchen, and in the tests it showed susceptibility. The one exception was the severely damaged field of O.A.C. 21 at Instow. In the nurseries O.A.C. 21 was not particularly susceptible. Apparently conditions were abnormally favourable for sawfly damage in that particular field.

It would appear that certain varieties of barley, notably Hannchen, serve as hosts for sawfly. However, even in Hannchen the small amount of cutting sustained in all nurseries except those at Swift Current suggests that the insect would have difficulty in maintaining itself on this variety alone. Further information is needed on the emergence of adults and their fecundity before the suitability of this variety as a host plant can be completely assessed. There is no doubt, however, that the sawflies from Hannchen stubble would constitute a serious menace to adjacent wheat. Furthermore, there may be some varieties of barley more susceptible than Hannchen, as indicated from the data presented in Table 7. In most instances the damage in the nurseries was not as great as that found in the field. Hence it may be possible that under different environmental conditions greater damage may occur. However, there is no evidence to suggest that any barley is likely to suffer damage to the same extent as Apex, Marquis or Thatcher wheat.

The greatest menace from sawflies in barley is not so much the loss to the barley crop as the potential menace to adjacent wheat from sawflies emerging from barley stubble. Barley is widely used to clean up severely infested areas, which are then returned to wheat production. Observations indicate that only rarely has wheat sown under such circumstances suffered damage. This is probably because the barleys grown in the sawfly area are almost entirely Trebi, Newal, Plush and Prospect. These varieties are quite resistant according to the results of the present investigation. This happy state of affairs occurred by chance but may not be maintained unless precautions are taken. Many new varieties and hybrid lines have been produced that show promise, agronomically, in the sawfly area. It is entirely possible that some of these, at least, are susceptible to sawfly damage. It appears desirable to determine the sawfly reactions of such varieties before they are recommended for commercial production. There is apparently a wealth of material that has resistance, and therefore it should be relatively easy to maintain this in any new varieties that are produced for this area.

SUMMARY

In recent years growers on the open plains of western Canada have been seeding barley early, whereas formerly the practice had been to sow late. By seeding early they exposed the crop to attack by the wheat stem sawfly (*Cephus cinctus* Nort.). Field observations showed that practically no damage was sustained by the varieties Prospect and Newal, when seeded early. Investigations of reports of severe damage to barley showed that in all cases, except one, Hannchen was the variety grown, thus indicating that varietal differences existed.

Nine varieties were seeded in replicated, single-row plots in various locations in 1944 and 1945. Significant varietal differences in infestation were established in all nurseries and in cutting in all but one nursery.

These results were in general agreement with previous field observations. From the standpoint of both infestation and cutting there was a tendency for the varieties to fall in the same order. Trebi was the most resistant; Plush, Prospect and Newal were almost equally so; while Hannchen and Rex were the most susceptible to damage. None of the barleys sustained damage to the same extent as adjacent plots of Apex, Marquis or Thatcher wheat. Parasitism of sawflies in barley, by *Microbracon cephi* Gahan, was much greater than in wheat. The amount of damage to the barley varieties varied greatly from station to station, indicating that environmental factors influence the degree of damage.

It is pointed out that even though the economic damage to susceptible barleys is relatively small, such fields provide reservoirs of infestation that are a menace to nearby wheat. At present the barley acreage in the sawfly area is now seeded almost exclusively to sawfly resistant varieties. It is suggested that the introduction of susceptible varieties be avoided.

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PRELIMINARY OBSERVATIONS ON SOME EFFECTS OF ARTIFICIAL DEFOLIATION OF WHEAT PLANTS[1]

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Grasshoppers are among the most widespread and persistent pests of cereals that occur on the Canadian prairies. Even though they can be controlled, they frequently damage plants and cause serious losses that may be overlooked. It is quite a common occurrence for newly hatched 'hoppers to devour all the leaves of young wheat plants, leaving the field apparently quite bare. Older 'hoppers and adults will frequently strip he leaves from well developed plants, leaving only a bare stem with the head intact.

If the grasshoppers are destroyed, the plants will sometimes appear to recover, put out new leaves and develop fairly normally. At such times the question arises as to what effect this leaf removal has actually had on the ultimate yield or quality of the grain. The answers to this question by cerealists and agronomists have been so contradictory that a small-scale experiment was started in 1936 to secure some definite information. The results were so marked that the experiment was repeated in 1937 on a larger scale. In both of these experiments there were errors in planning which could not be foreseen and which seriously affected the results. These faults were corrected in 1938 and the experiment conducted for a third time.

The results of the 1938 experiment agreed in the chief essentials with the experiments of the two previous years. The crop suffered the most damage by defoliation when it was heading out and blooming but appeared to benefit by this operation when it was ripening.

METHODS

Fifteen plots of wheat, each consisting of 14 rod-rows, were seeded with a Kemp hand drill on April 25. The rows were spaced 1 foot apart, and 200 kernels of registered Marquis wheat were seeded in each row. The plots were arranged in 5 rows of 3 plots each, with a space of 4 feet between the rows of plots and a space of 1 foot between the plots in each row. Wheat was sown with a drill around the four sides of the block of plots to offset marginal effect.

An effort was made to simulate grasshopper damage in 12 of the 15 plots, the other 3 being left as checks. The checks were located as follows:— No. 3, the right-hand plot in the first row; No. 8, the centre plot in the third row; and No. 13, the left-hand plot in the fifth row. Thus the check plots were placed diagonally across the block of plots. When No. 15 was about to be clipped it was found that practically all of the leaves were dried up and it appeared as if defoliation would have no effect. For this reason only half of the plot was defoliated, the other half, No. 15*b*, being used as an additional check.

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In plots Nos. 1 and 2 the plants were cut off at the ground level. In the remaining plots the leaves were removed, leaving the main stem intact, as has frequently been observed where grasshoppers have been abundant. Each plot received the one defoliation only and was left untouched for the remainder of the season, as would happen if an invasion had been controlled at that time and there had been no further infestation.

The first plot was cut on May 10 when the plants were ½ to 1½ inches high. The leaves were cut from the plants in the remaining 11 plots in successive weeks.

When the plants came through the ground it was evident that there were not 200 in each row, so an attempt was made to count them. By the time the last plots were counted considerable stooling had taken place and it was found to be impossible to make an accurate check. This was compensated for to some extent by recording the number of heads at the time the plots were harvested.

Soil moisture samples were taken in each plot in May, June and July, but as there was a mean variation of only 1.1% between the wettest and driest plots, the moisture content was disregarded in analyzing the results of the experiment.

As the crop in each plot ripened, the 10 centre rows were harvested by hand, the two outside rows having been seeded to offset marginal effect. The grain was threshed in a rod-row thresher, and while some kernels were lost in the threshing, this loss was probably proportionally the same for each plot, so it was disregarded.

RESULTS

Table 1 and Figure 1 contain the data obtained from this project; these data may be summarized as follows.

Yield

The mean of the check plots was 48.6 bushels per acre. The first three plots defoliated suffered a loss of 12.6 to 16.8%, the next four 4.3 to 9.6%, the next three 20.3 to 29.1%, the second last 0.5%, and the last plot showed a *gain* of 2.9%. The three plots which suffered most severely were defoliated during the period of heading-out to just after blooming.

Grade

The grain from all plots was No. 1 Hard in milling quality, but that from 14 plots lacked the required weight to qualify for this grade. The other plot was defoliated on June 20, a week before the grain headed out. Ten of the plots graded No. 1 N., and four, including one of the check plots, graded No. 2 N.

Days Required to Mature

The defoliated plots required 1.9 days longer to mature than the mean of the check plots. The first plot clipped matured 1 day earlier than any of the checks. All of the other defoliated plots were 5 to 7 days longer in maturing than No. 1 plot.

TABLE 1.—EFFECT ON CROP OF DEFOLIATION OF WHEAT

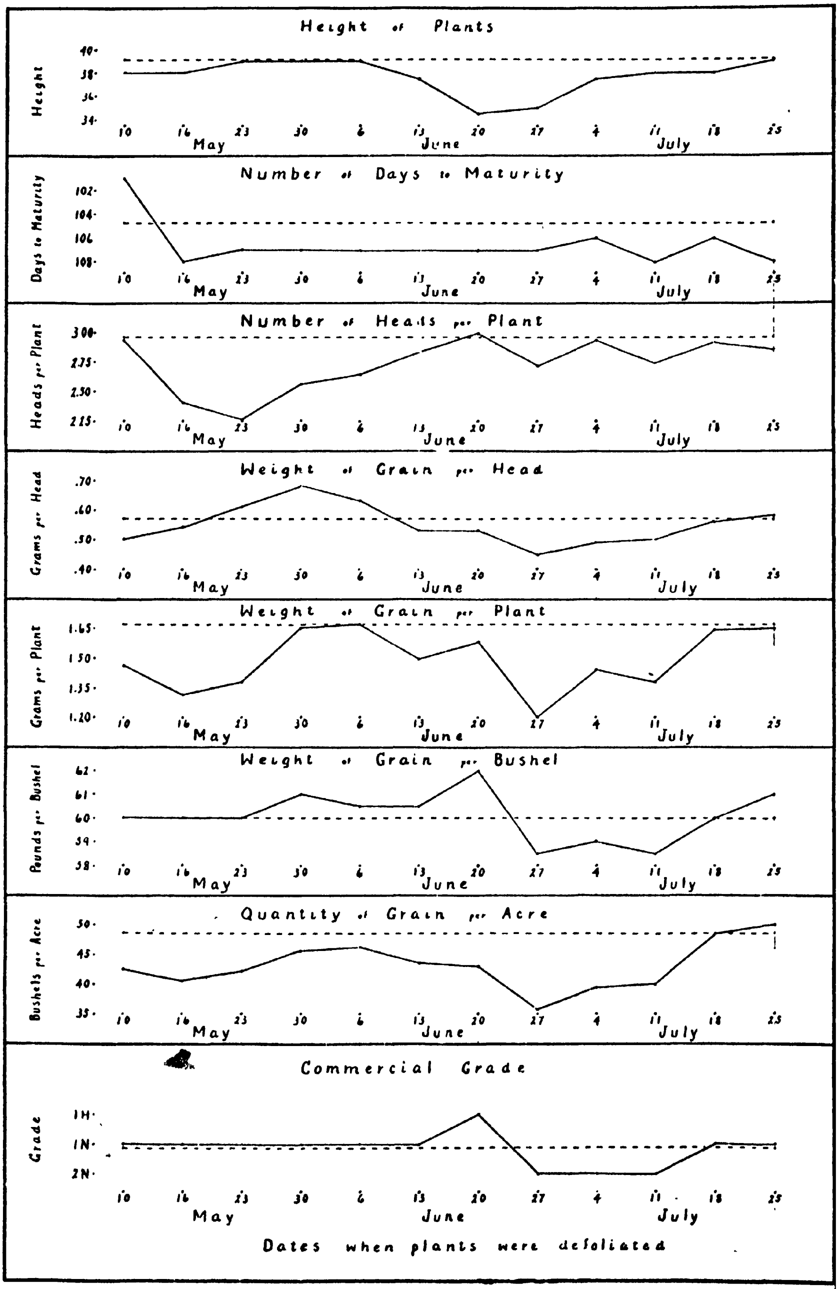
Plot No.	Date clipped	No. days from seeding	Stage of wheat	Height of ripe wheat	Number of			Weight of grain per				Bushels per acre	Pounds per acre	Grade	Mean soil moisture	No. days to cutting
					Plants	Heads	Heads per plant	Plot	Plant	Head	Bushel					
				(inches)				(grams)	(grams)	(grams)	(pounds)					
1	May 10	15	¾ – 1¼ inches	38.0	1,743	5,102	2.93	2,548	1.46	.50	60.0	42.5	2,550	1 N	13.3	101.0
2	May 16	22	2¼ inches (1–5 leaf)	38.0	1,860	4,473	2.40	2,428	1.31	.54	60.0	40.5	2,430	1 N	13.3	108.0
4	May 23	29	3 inches	39.0	1,833	4,136	2.26	2,529	1.38	.61	60.0	42.1	2,526	1 N	14.0	107.0
5	May 30	36	4 inches	39.0	1,655	4,031	2.56	2,735	1.65	.68	61.0	45.6	2,782	1 N	14.0	107.0
6	June 6	43	6 inches	39.0	1,663	4,390	2.64	2,772	1.67	.63	60.5	46.2	2,795	1 N	14.2	107.0
7	June 13	50	—	37.5	1,756	4,964	2.83	2,617	1.49	.53	60.5	43.6	2,638	1 N	14.0	107.0
9	June 20	57	—	34.5	1,628	4,882	2.99	2,581	1.58	.53	62.0	43.0	2,666	1 H	14.3	107.0
10	June 27	64	Heading	35.0	1,748	4,761	2.72	2,145	1.20	.45	58.5	35.7	2,088	2 N	13.6	107.0
11	July 4	71	Blooming	37.5	1,641	4,812	2.93	2,360	1.44	.49	59.0	39.3	2,318	2 N	13.8	106.0
12	July 11	78	—	38.0	1,742	4,774	2.74	2,399	1.38	.50	58.5	40.0	2,340	2 N	14.1	108.0
14	July 18	85	—	38.0	1,774	5,180	2.92	2,902	1.64	.56	60.0	48.4	2,904	1 N	13.5	106.0
*15a	July 25	92	Wheat ripening, leaves all brown	39.0	909	2,598	2.86	1,499	1.65	.58	61.0	50.0	3,005	1 N	13.5	108.0
	Mean			37.7	1,735	4,705	2.73	2,567	1.48	.55	60.1	43.1	2,587	1 N	—	106.6
3	Check			39.0	1,785	4,988	2.79	2,943	1.65	.59	61.0	49.0	2,989	1 N	13.6	102.0
8	Check			40.0	1,629	5,048	3.09	2,931	1.80	.58	60.0	48.9	2,934	1 N	14.3	103.0
13	Check			38.5	1,792	5,360	2.99	2,825	1.58	.53	59.0	47.1	2,779	2 N	13.2	106.0
*15b	Check			39.0	839	2,630	2.96	1,489	1.67	.57	60.5	49.6	2,976	1 N	13.5	108.0
	Mean			39.1	1,742	5,150	2.96	2,911	1.67	.57	60.0	48.6	2,919	1 N	—	104.7

* Five rows only.

Figure No. 1

SOME EFFECTS OF ARTIFICIAL DEFOLIATION

Legend—
——Defoliated Plots
- - - -Check Plots



Height of Plants

The plants in the defoliated plots were all slightly shorter than those of the mean of the checks, while in two plots they were 4 to $4\frac{1}{2}$ inches shorter. One of these latter plots was clipped when the wheat was heading out and the other during the previous week.

Number of Heads per Plant

There was a serious reduction in the number of heads per plant in the plots defoliated in the second to the fifth weeks, inclusive, but in the other plots the reduction was not conspicuous.

Weight of Grain per Plant

Only No. 6 plot, defoliated on June 6, produced as much grain per plant as the mean of the check plots. The plants in the first three plots and in the eighth to the tenth all suffered quite severely. The last two plots of the series were not materially affected.

In summarizing the results of the experiment one is forced to the conclusion that defoliation of the wheat plant is detrimental at any stage in its development except during the last two weeks before the grain is ripe, at which time the operation appears to be beneficial.

SUMMARY

1. Defoliation of the wheat plant, at any stage in its development, did not necessarily result in crop failure.

2. The yield suffered most when the plant was defoliated during the heading to dough stages.

3. Defoliation of the plant during the two weeks previous to its maturity was not injurious to the plant, as indicated by the yield.

4. Defoliation of the growing plant did not affect the quality of the grain but did affect the quantity and also the weight of grain per bushel.

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BOOK REVIEW

CANADIAN AGRICULTURAL POLICY—THE HISTORICAL PATTERN, by Veron C. Fowke, The University of Toronto Press, 304 pages, 1946. $3.50.

Farmers to-day are actively interested in agricultural policy. With the painful experiences of Post-World War I, and the depression years of the 1930's still distinct, they are anxious to consolidate their gains and attain a stability that may come out of a price support program. That the farmers can attain this by sheer pressure weight of political influences is not necessarily true. Professor Fowke's study leads him to believe that: "There is little justification for the general impression that down through the generations the embattled Canadian farmer has won grudging concessions from the entrenched interests of commerce, finance, and industry, either by the pressure of endless complaint or by an appeal to reason and justice. The Canadian farmer has had political power, but this power has varied in proportion to the contribution which agriculture could make, at any given time, to the cause of commerce, finance, and industry, rather than in proportion to farmers' numbers or their state of organization."

This book is timely and fills an important need by providing a historical perspective of Canadian agricultural policy. The book is not only useful to those who actively make policy but to those who teach it.

Professor Fowke divided his book into two parts, the first entitled the Pre-Confederation Period, and the second part Federal Agricultural Policy. In the second part he reviews the division of powers between the federal and provincial governments at Confederation, the encouragement of immigration and settlement, the livestock and dairy industries, and the production and marketing of wheat.

Professor Fowke concludes that: "As for providing investment opportunities, the frontier role, Canadian agriculture excelled in this capacity from 1900 to 1930 during the opening up of wheat production in the Canadian West...... The vital frontier of Canadian investment in fixed equipment since 1930 has been in the Precambrian Shield instead of in the Agricultural West, in newsprint and minerals instead of in wheat. These facts call for a new Canadian philosophy not only of agricultural functions and agricultural policy, but also of the relationship between the federal and provincial governments in regard to agriculture."

—FRANK SHEFRIN.

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THE REACTION OF WHEAT VARIETIES TO WHEAT STEM SAWFLY ATTACK[1]

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The wheat stem sawfly (*Cephus cinctus* Nort.) is a major limiting factor in the production of wheat in many areas of the Prairie Provinces. The loss has been estimated by Farstad (unpublished) at approximately 20 million bushels annually. This sawfly is a native of the mixed grass prairies where it infested various grasses chiefly *Agropyron* species. It was first reported attacking wheat in Canada at Souris, Manitoba, by Fletcher in 1895 (10). Since that time it has increased steadily in economic importance.

The region where this insect is causing or is likely to cause important economic losses is shown in Figure 1. It will be noted that this area coincides closely with the brown and dark brown soil zones of Alberta and Saskatchewan. These are the major wheat producing areas in these provinces and, incidentally, the areas in which the highest quality wheat is produced. Damage outside this area (in the black soil zone) occurs from time to time, but the economic hazard is slight because the pest can usually be controlled by the crop rotations in common use there.

LITERATURE

Criddle (5, 6) and Seamans (19) have outlined the life history and habits of the sawfly. The adult emerges from early June until mid-July. The date of first emergence and the length of flight depend on weather conditions. Eggs are deposited inside the developing wheat stem. Stems that have reached the "boot" stage are favoured for oviposition but stems at an earlier or later stage may also be infested. The young larva feeds on the inside of the stem, probably on the food materials being transported in the vascular tissue. As the plant reaches maturity the larva migrates to the base of the stem, where it girdles the culm at ground level causing the stem to break easily and fall to the ground. Such stems are difficult to retrieve with modern harvesting equipment and constitute the chief loss from the activities of this insect. The larva overwinters in the stub and pupates during the spring just before emergence as an adult.

In addition to the damage described above, Seamans *et al.* (20) has shown that substantial losses in yield and quality of grain are sustained as a result of the tunnelling and feeding of the larvae inside the culms. This type of damage has not been taken into consideration in evaluating varietal

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Contribution No. 2410 of the Division of Entomology.

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resistance by the investigators whose work is reviewed herein or by the authors in the present study. In all cases damage refers only to the breakage of stems as a result of sawfly activity. The reason for this is that the damage described by Seamans *et al.* (20) is difficult to evaluate and, in all probability, a close correlation exists between resistance to tunnelling and feeding and resistance to stem cutting. Furthermore should a variety resistant to stem cutting become established in a district the sawfly population would be greatly reduced and damage from tunnelling and feeding would become of minor importance.

Throughout this paper the term *vulgare* is used to refer to all varieties of the species *Triticum vulgare* Host. and the term *durum* to all varieties of the species *T. durum* Desf.

Evidence of differences in sawfly damage among wheat varieties has been reported by Ainslie (1), Criddle (5, 6) and Scegolev (18). The literature on insect resistance in crops plants has recently been reviewed by Snelling (21) and Platt and Farstad (15) and the Imperial Bureau of Plant Breeding and Genetics has issued a bibliography on insect pest resistance in plants (2).

A co-operative project between the Dominion Experimental Station, Swift Current, and the Dominion Entomological Laboratory, Lethbridge, was initiated to study sawfly resistance in wheat varieties. Results from this project were reported by Kemp (12) in 1934. He found that solid-stemmed varieties were cut by the sawfly less frequently than hollow-stemmed ones. Among the solid-stemmed types were certain vulgare varieties that Kemp imported from New Zealand, but which originally came from the Mediterranean region. Farstad (8) reported in 1940 that these solid-stemmed wheats were more resistant to cutting, that there was a higher larval mortality in such varieties, and that the fecundity of the adult tended to be reduced.

Platt (14) studied the effect of environmental factors on the solid-stem character. It was found that in solid-stemmed vulgare varieties the amount of solidness was greatest under long hours of sunshine and low rainfall and least under conditions of reduced sunshine and high rainfall. Continuous shading resulted in completely hollow culms. The solid-stemmed durum variety Golden Ball retained its solidness under all conditions in which it was tested. As a result of these studies it was postulated that the sawfly damage to solid-stemmed vulgare varieties could be expected to vary with variations in environmental condition. Golden Ball, on the other hand, could be expected to retain its resistance to a much greater degree.

The inheritance of solid stem in crosses between solid and hollow vulgare varieties was found by Platt *et al.* (16) to depend on three factor pairs. Platt and Larson (17) were unsuccessful in their attempt to transfer solid stem from Golden Ball durum to hollow-stemmed vulgare wheats. They suggest that there is a gene in the C genom that is epistatic to all other genes for solidness.

All of the solid-stemmed varieties that had been imported were agronomically undesirable when compared with existing Canadian varieties. Therefore, a breeding program was initiated to transfer their sawfly re-

sistance to agronomically desirable types. It was realized that in evaluating the lines produced in this program it would be necessary to develop an efficient, rapid technique to determine the reaction to sawfly of a large number of lines. In testing for sawfly resistance it was deemed necessary to study the effect of the insect on the plant and of the plant on the insect. Studies on the effect of the insect on the plant, i.e. the damage sustained by varieties in the various tests that have been conducted in the last six years, are summarized in this paper. Studies on the effect of the plant on the insect, i.e. the mortality and fecundity of the insect when reared on different varieties, will be reported in later papers.

PRELIMINARY EXPERIMENTS

Varietal Tests

In 1940 a total of 175 varieties of durum and vulgare wheat were grown at Swift Current in single rod row plots. They were exposed to a severe natural infestation of sawflies. At maturity the percentage of stems cut was determined by counts. The results showed that the durums as a class were resistant and that the solid-stemmed vulgare varieties were more resistant than the hollow ones. The results also indicated that varietal differences might exist within each of these groups. In general the commonly grown Canadian vulgare varieties were the most susceptible of the entire group.

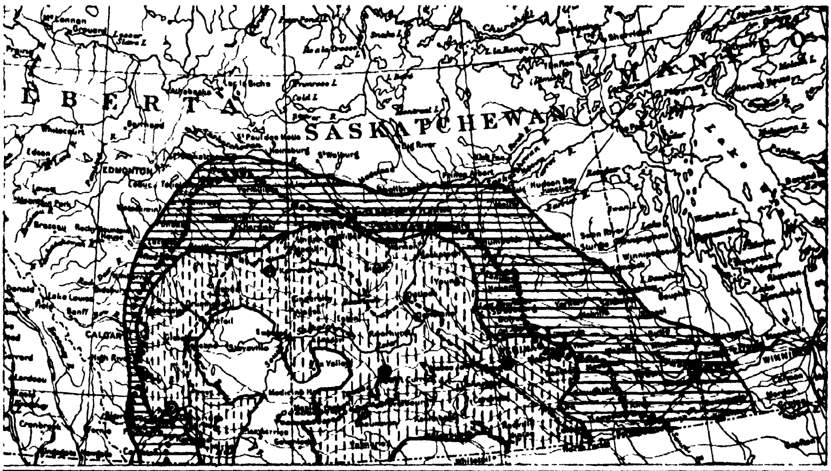
A test of 24 varieties and hybrid lines was grown at Swift Current and Scott in the same year. The varieties were grown in single rod row plots, duplicated and arranged as randomized blocks at each point. The results showed a statistically significant variety—station interaction. It was thus apparent that in order to obtain reliable results it would be necessary to make tests at a series of stations.

Use of Cages

Considerable experience was gained in early experiments in the use of screen-wire cages for resistance studies. The varieties were grown on plots 4 × 6 feet in size and each plot was covered with a screen-wire cage. The number of sawflies required was then introduced into the cage. This method had two important advantages: first, the sawfly population on each variety could be controlled, and second, sawflies from different areas could be tested under comparable conditions. However, results were very disappointing because the resistant varieties failed to maintain their resistance under such conditions. For example, in one experiment S-615 (a resistant line) was cut 46% inside and 9% outside the cage; whereas Marquis (a susceptible variety) was cut 69 and 74% respectively. It is thought that the shading effect of the cages on the solid-stemmed lines reduced their solidness and hence their resistance. The cages have the additional disadvantage of being costly and the handling requires a large amount of labour. They offer little promise in the technique of testing varietal reaction in this type of resistance.

METHODS

With the preliminary results in mind, a series of uniform sawfly nurseries was established in 1941 and these are still being used. The general plan was to grow a series of varieties at a number of points throughout the sawfly area in locations that would expose the varieties to a severe



Area of severe infestation. Infestations have been generally severe during past ten years.

Area of light to moderate infestation. Infestations may build up to severe during a series of dry years but cropping practice and parasitism contribute to keeping pest under control.

Area of light infestation. Sub-marginal land, rolling topography, range land, with relatively small wheat acreage.

Boundary of dark brown soil zone.

Boundary of brown soil zone.

⊙ Locations of sawfly nurseries.

FIGURE 1. Map showing distribution of wheat stem sawfly in relation to soil zones.

natural infestation of sawflies. These nurseries were located at the Dominion Experimental Stations at Swift Current and Scott, at the Dominion Experimental Substation at Regina and the Dominion District Experimental Substation at Nobleford in each of the years 1941 to 1945; at the Dominion District Experimental Substations at Consort (1941–42), Riverhurst (1941) and Shaunavon (1943–45), and at the Dominion Experimental Farm at Brandon in 1942. The locations of these points are shown in Figure 1.

At each point the nursery was located on summerfallow adjacent to infested wheat stubble. The plots were placed at right angles to the source of infestation. This plan allowed for all plots to be equally exposed to infestation in so far as this was possible. The general plan of a typical nursery is shown in Figure 2. Each plot consisted of a single row 10 feet long. The rows were spaced 1 foot apart and each variety was seeded at the rate of approximately 1¼ bushels per acre. In 1941 and 1942 three replicates were used and in subsequent years five replicates. From 1941 to 1943 the varieties were arranged in randomized blocks and durum and

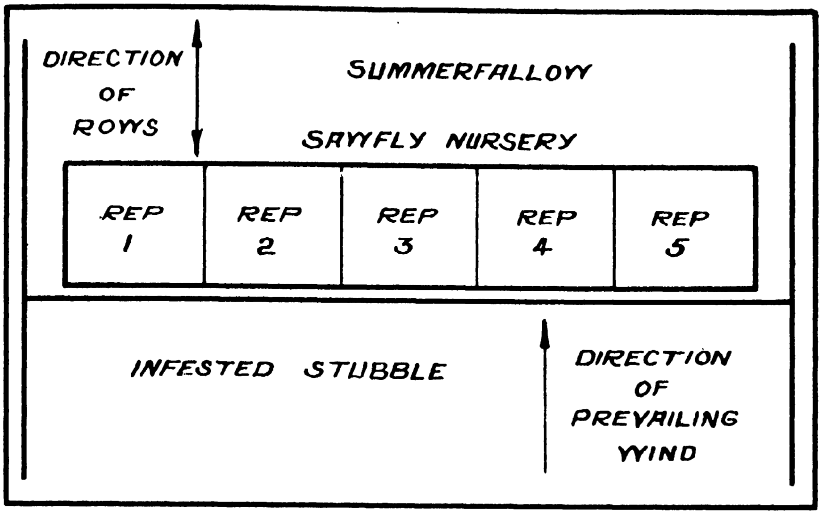


FIGURE 2. Field plan showing the location of a sawfly nursery in the field and the general plan of the nursery.

vulgare plots were intermixed. The two types were separated in 1944 when the 16 durum varieties were arranged in a complete lattice design and the 64 vulgare wheats in a quintuple lattice design (Goulden (11)). The blocks of the durum and bread wheats were randomized within each replicate thus allowing for a comparison within and between groups. Border rows were grown between durum and vulgare blocks in that year. A similar arrangement was used in 1945 except that border rows were dispensed with.

The nurseries were seeded early. According to Farstad (9) early seeded wheat is usually the most attractive to sawflies and may be expected to suffer the maximum damage.

Damage was estimated in the following manner. In 1941 the total culms in the plot and the number of culms severed by the larvae, excluding end plants, were counted about 10 days after the latest variety matured. This method was time consuming and laborious and would definitely limit the amount of material that could be handled. In 1942 the stubble from each row was lifted, bagged and shipped to Swift Current, and during the winter damage counts were made. This method proved very unsatisfactory; breakage of the stubble in handling and transit was difficult to differentiate from sawfly damage, the total labour required was great and the results delayed unduly. The following plan was adopted in subsequent years. Each of the authors made independent estimates of the percentage cut in each plot. The estimates were then compared and when discrepancies occurred the plot was re-examined and, if necessary, counts were made.

For the analysis of the data the percentage values were transformed to $\sin^2 \theta$ according to Bliss (3).

STUDIES ON INFESTATION

A variety will obviously escape damage if the adult fly fails to oviposit in the culms. Such a failure might result from inherent resistance to oviposition or from preferential oviposition where a choice of many varieties is available as in varietal test plots. Kemp (12) and Farstad (8) attribute resistance mainly to the ability of the variety to tolerate or destroy the egg or larva after it is deposited rather than to resistance to oviposition. However, their data suggest that differential oviposition may occur to a sufficient extent to be a factor in evaluating resistance. In fact, Kemp used the percentage of infested stems that were cut as a criterion of resistance.

In order to obtain information on the effect that differences in infestation were likely to have in varietal testing, 25 culms in each plot from 5 of the nurseries grown in 1941 were examined. These examinations were made soon after oviposition was complete. If the culm showed an egg or larva either alive or dead, it was considered infested.

TABLE 1.—MEAN PERCENT INFESTED AND NUMBERS OF VARIETIES DEVIATING SIGNIFICANTLY FROM THE MEAN IN THE 1941 NURSERIES. A TOTAL OF 64 VULGARE AND 24 DURUM VARIETIES WERE TESTED

	Species	Station				
		Scott	Swift Current	Noble-ford	River-hurst	Regina
Mean % infested	—	94	94	76	88	82
No. var. with significantly higher infestation than mean	*T. vulgare*	0	0	0	0	0
	T. durum	0	0	0	0	0
No. var. with significantly lower infestation than mean	*T. vulgare*	6	6	3	1	8
	T. durum	0	3	0	1	2

Statistically significant varietal differences in percentage infestation were established at each nursery, thus showing that certain varieties were infested to a greater degree than others. Some of the results obtained are summarized in Table 1. There were 17 different varieties out of a possible 24 represented in the vulgare wheats that had lower infestations than the general mean. No single variety was significantly lower at all stations. Fifteen of the 17 were late maturing varieties (a week or more later than Marquis). Two other wheats, *T. dicoccum* and *T. timopheevi* carried much lower infestations than any other varieties in the test. The former made very poor growth and had very fine stems that were apparently not attracrive to the insect, while the latter had densely pubescent culms which may have deterred the flies. When these wheats were caged in 1942 the sawflies oviposited freely, infesting them 100%.

The results show that none of the varieties tested had any particular resistance to oviposition, but they also show that some varieties partially escape infestation in varietal test plots. To the extent that they escape infestation they will also escape damage and hence will appear more resistant than they actually are. The question then arises as to whether percentage cut is a suitable index of resistance or if this figure should be

adjusted according to the infestation. To obtain information on this point the mean values, all Stations, for percentage cut were adjusted according to the mean percentage infested, all Stations, i.e., the percentage of the infested stems cut was calculated for each variety. These adjusted values were correlated with the figures for percentage cut. A correlation coefficient of 0.987 was obtained. This very high value was apparently obtained because the infestation of relatively few varieties deviated greatly from the general mean, and because of averaging the results from all Stations, and the relatively great differences between varieties in percentage cut as compared to the small differences in infestation. It is apparent that under the conditions prevailing in these tests differences in infestation, on the average, are of no particular importance in evaluating resistance. However, heavy infestations were obtained in the nurseries concerned and it is entirely possible that different results would be obtained if the mean percentage infested was 50 or less.

To determine accurately the infestation in a large series of plots is very laborious. It is relatively easy to determine infestation in hollow stemmed varieties as the lumen of the culm can be examined by splitting, but in solid-stemmed types it is much more difficult as the culm must be shaved off in thin layers and examined very closely, particularly for eggs and dead immature larvae. Furthermore this work must be conducted shortly after oviposition is complete as dead larvae tend to disintegrate and disappear. For these reasons the infestation was not taken on all plots in subsequent years, but in order to obtain further information on varietal reaction and on the uniformity of infestation throughout a nursery the following procedure was adopted:

1. When oviposition was complete the infestation in a series of susceptible hollow-stemmed checks was noted. This provided information pertaining to the extent and uniformity of the infestation throughout the nursery.

2. All plots that differed materially from the checks in stage of development, either through differences in rate of growth or as a result of rodent or other injury, were examined and the infestation noted. Similarily infestation was noted on all exotic types.

3. The infestation of one or two resistant checks was noted.

The results from these observations showed even less evidence of varietal differences in infestation than was obtained in 1941. This can probably be attributed to the fact that the very late maturing types that appeared in the 1941 tests were discarded and did not appear in subsequent years. In one nursery, Swift Current 1942, the infestation was not uniform throughout a replicate. This nursery was arranged in the field in a different manner from that shown in Figure 2. The replicates were placed side by side rather than end to end. The sawflies entered the nursery from the ends of the replicates and were few in number; hence one end of each replicate was heavily infested and the other end was practically free from infestation. As a result the nursery was abandoned and no data on damage to the varieties secured. This was the only nursery in all those conducted where the infestation was not uniform throughout. The failure of this nursery was largely due to an improper field arrangement.

REACTION TO DAMAGE

During the period 1941–45 a total of 28 nurseries were planted. Twenty-four of these yielded data on varietal reactions while four were failures and were discarded. One of the four failures, namely the 1942 nursery at Swift Current, has been discussed; a second failed because there were insufficient sawflies to produce damage; a third was discarded because of extensive parasitism of the sawfly larvae by *Microbracon cephi* (Gahan);

TABLE 2.—MEANS, STANDARD ERRORS, ETC. OF DATA ON SAWFLY DAMAGE TO WHEAT VARIETIES. PERCENT CUT TRANSFORMED TO $\sin^2 \theta$

Station	Year		Mean	S.E.	S.E. in percent.	Min. sig. diff.	F[3]
Scott	1941		44.5	4.02	9.0	11.2	14.10
	1942		25.8	3.20	12.4	9.0	5.72
	1943		37.1	3.21	8.6	8.9	21.48
	1944	(1)[1]	20.0	2.43	12.2	6.7	13.30
		(2)[2]	8.1	0.93	11.5	2.6	3.14
	1945	(1)	19.0	1.81	9.5	5.0	124.42
		(2)	34.2	6.02	17.6	16.7	4.76
Nobleford	1941		36.4	4.42	12.1	12.5	11.17
	1942		32.9	5.14	15.6	14.4	9.25
	1943		18.2	2.10	11.5	5.8	56.56
	1944	(1)	18.9	3.30	18.9	9.2	14.79
		(2)	6.6	1.61	24.5	4.5	1.77
	1945	(1)	17.1	2.45	14.3	6.8	56.02
		(2)	27.4	2.43	8.9	6.7	24.28
Swift Current	1941		40.0	4.83	12.1	13.5	3.59
	1943		30.6	3.34	10.9	9.3	21.83
	1944	(1)	44.8	3.50	7.8	9.7	44.95
		(2)	9.9	1.14	11.5	3.2	2.25
	1945	(1)	19.0	1.29	6.8	3.6	338.52
		(2)	11.6	1.10	9.5	3.1	14.18
Regina	1941		47.6	4.41	9.3	12.3	14.02
	1942		32.4	5.12	15.8	14.3	5.81
	1943		42.3	3.58	8.5	10.0	27.28
	1945	(1)	62.0	2.14	3.4	5.9	28.79
		(2)	35.8	2.35	6.6	6.5	11.23
Shaunavon	1943		37.8	3.00	7.9	8.3	35.14
	1944	(1)	34.3	3.04	8.8	8.4	42.44
		(2)	13.9	1.62	11.6	4.6	5.00
	1945	(1)	26.2	2.06	7.9	5.7	89.59
		(2)	36.2	2.79	7.7	7.7	16.99
Riverhurst	1941		38.1	4.37	11.5	12.2	6.34
Consort	1941		15.3	4.01	26.3	11.2	7.24
Brandon	1942		28.9	4.71	16.3	13.2	6.89

[1] Refers to test of varieties of *T. vulgare*.
[2] Refers to test of varieties of *T. durum*.
[3] All values except that for Nobleford, 1944 (2) exceed the one percent point.

while the fourth was a crop failure. The values for means, standard errors and F values for the 24 successful nurseries are presented in Table 2. Note that in this Table and in Table 4 the percentage cut has been transformed to $\sin^2 \theta$ and these are the only values used. The damage values together with the calculated errors cannot be transformed back to percentage figures, hence statistical differences between varieties can only be made on the bases of transformed values. For a discussion of this point see Cochran (4). Except for the test of durums at Nobleford in 1944 significant varietal differences were established in all nurseries.

During the course of the study many varieties and hybrid lines were tested. Space will not permit including data on all of these. Data on the damage sustained by some of the more common varieties of vulgare and durum are presented in Table 3. Upon request the authors would be glad to supply any data that are available on the reaction of particular varieties.

TABLE 3.—PERCENT CUTTING BY SAWFLIES IN WHEAT VARIETIES 1941–45

Variety	C.A.N.*	Percent cut					
		Av. 6 stat. 1941	Av. 4 stat. 1942	Av. 5 stat. 1943	Av. 4 stat. 1944	Av. 5 stat. 1945	Av. all stations
		Varieties of *T. vulgare*					
Apex	1909	69.8	53.5	74.7	55.1	82.6	68.3
Bena	1817	46.6	33.2	71.6	—	—	—
Cadet	3627	—	—	—	51.5	—	—
Caesium	1256	50.2	38.3	69.6	—	—	—
Canus	1260	59.9	46.0	65.3	—	—	—
Diament	1278	49.4	—	—	—	—	—
Garnet	1316	54.7	60.3	83.9	59.4	—	—
Gluford	—	50.7	36.7	60.8	—	—	—
Gluyas	—	15.9	25.3	38.8	—	—	—
Hope	1339	46.2	42.4	67.6	—	—	—
Indian Dwarf	—	—	25.4	—	—	—	—
Lohman's Wender	1387	48.4	—	—	—	—	—
Marquis	1831	61.2	41.6	68.7	52.6	79.2	61.8
McMurchay's Sel.	3626	62.5	—	—	—	—	—
Mida	3598	—	—	—	52.8	—	—
Milturum 0.321	1415	45.6	19.7	64.4	—	—	—
Nabawa	1818	—	—	—	45.8	—	—
Newthatch	3597	—	—	—	37.8	—	—
Ramona	3581	60.7	—	—	—	—	—
Red Bobs	1637	61.5	45.3	60.9	35.0	72.2	56.5
Regent	1938	52.2	39.3	62.2	47.6	80.0	57.2
Reliance	1503	65.0	44.6	67.4	—	—	—
Renown	1915	58.6	51.7	73.2	—	—	—
Reward	1509	60.4	54.7	67.6	44.4	—	—
Sultan	—	58.4	47.7	67.4	—	—	—
Thatcher	1820	60.9	47.6	69.2	43.8	75.9	60.7
Waratah	—	42.6	—	—	—	—	—
S-615	3577	14.1	22.6	10.6	4.0	16.3	13.6
S-633	3578	26.6	42.9	28.4	7.[illegible]	27.9	26.7
		Varieties of *T. durum*					
Aranautka	1213	34.1	5.1	—	—	—	—
Carleton	3527	—	—	—	3.3	33.2	—
Golden Ball	1325	11.2	5.5	5.4	0.8	9.0	6.8
Iumillo	1356	28.[illegible]	9.2	23.1	4.1	27.6	19.8
Kubanka	1386	27.2	9.6	19.2	—	—	—
Melanopus	1413	15.9	9.9	9.6	2.6	—	—
Mindum	1418	34.5	4.9	10.5	4.2	29.2	18.4
Monad	1778	22.7	4.2	11.6	—	—	—
Nodak	1427	28.9	—	—	—	—	—
Pelissier	1859	22.6	8.0	12.2	3.5	31.3	16.6
Sivousska No. 3	1523	17.4	8.3	7.9	3.6	20.1	12.2
Stewart	3599	—	—	—	4.8	40.7	—

* Canadian accession number.

None of the hollow-stemmed vulgare varieties has shown any high degree of resistance to sawfly attack. Nevertheless, differences among these types do exist. For example, Apex and Garnet were extremely

susceptible, whereas in most tests Regent and Red Bobs were considerably less so. A detailed comparison of the reactions of Apex and Regent is presented in Table 4. In all except two of the 24 nurseries the numerical damage values for Regent are lower than those for Apex, and in eight of the 24 the differences are statistically significant. No attempt has been made to investigate the characteristics that may be associated with these differences of susceptibility.

Differences were also found to exist among the solid-stemmed vulgare varieties. The two varieties S-615 and S-633 are equally solid-stemmed (14). The comparative data on the sawfly damage suffered by these varieties are presented in Table 4. In all cases S-633 had numerically higher ratings than S-615 and in 13 of the 24 nurseries the differences were statistically significant. Comparing S-615 (the most resistant solid-stemmed variety) with Apex (Table 4) it is noted that S-615 suffered significantly less damage in all nurseries. Compared with Regent, S-615 had numerically lower values in all nurseries and these differences were significant in 21 of the 24 trials.

The field appearance of resistant lines as compared with Apex (susceptible) is shown in Figure 3.

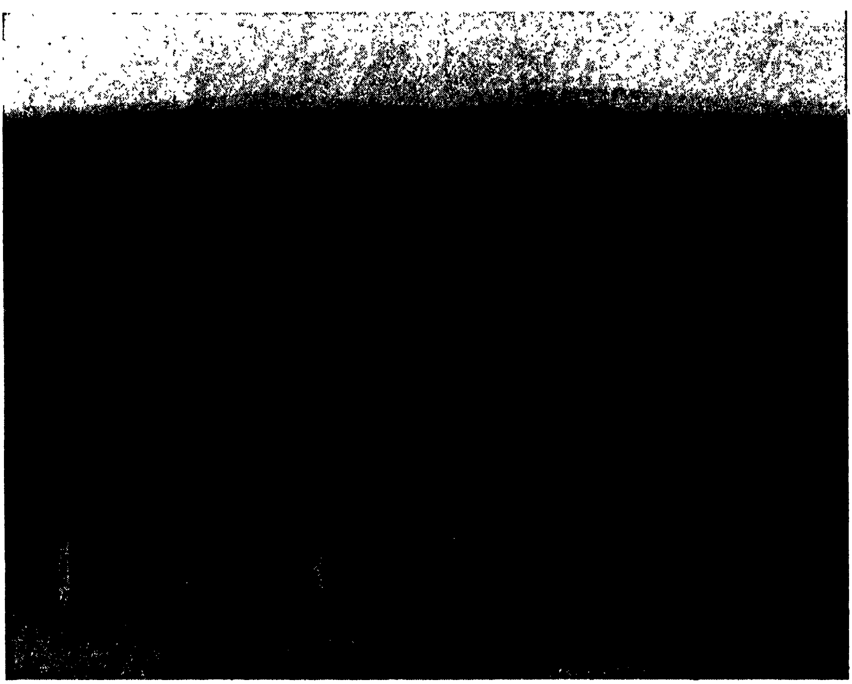


FIGURE 3. Sawfly damage to wheat varieties. Note the susceptible variety, left centre, as compared with resistant lines.

TABLE 4.—DAMAGE BY SAWFLIES TO WHEAT VARIETIES IN INDIVIDUAL TESTS, 1941–45. THE VALUES GIVEN ARE THE PERCENTAGE OF STEMS CUT TRANSFORMED TO SIN ^{2} θ

Station	Year	Percent cut transformed to sin² θ						
		Apex	Regent	S-615	S-633	Golden Ball	Mindum	Nec. diff[1]
Scott	1941	71.1	56.4	29.8	34.0	17.8	39.6	11.2
	1942	33.4	25.3	24.1	35.5	12.3	12.5	9.0
	1943	58.9	48.2	20.9	33.8	19.1	21.8	8.9
	1944	31.3	26.4	9.0	11.9	3.8	7.2	6.7 and 2.6
	1945	64.1	60.7	8.8	16.8	12.8	34.9	5.0 and 16.7
	Av.	51.8	43.4	18.5	26.4	13.2	23.2	—
Nobleford	1941	55.8	38.8	26.4	28.7	12.8	32.1	12.5
	1942	59.9	47.8	27.5	38.5	10.2	10.6	14.4
	1943	43.0	32.7	6.2	17.3	3.4	3.4	5.8
	1944	31.7	30.9	1.6	10.1	4.3	7.8	9.2 and 4.5
	1945	51.7	56.4	7.4	17.6	7.3	36.8	6.8 and 6.7
	Av.	48.4	41.3	13.8	22.4	7.6	18.1	—
Swift Current	1941	56.3	39.2	22.9	41.5	27.6	41.5	13.5
	1943	60.6	49.2	15.2	35.7	9.8	15.9	9.3
	1944	70.8	61.6	14.1	22.2	6.0	10.1	9.7 and 3.2
	1945	68.2	60.1	6.0	18.7	5.8	12.6	3.6 and 3.1
	Av.	64.0	52.5	14.6	29.5	12.3	20.0	—
Regina	1941	74.1	57.7	18.8	34.9	17.4	43.1	12.3
	1942	48.9	34.4	30.5	52.4	9.6	6.6	14.3
	1943	72.8	69.8	24.8	42.0	10.2	14.5	10.0
	1945	77.4	74.1	58.8	69.7	28.0	29.6	5.9 and 6.5
	Av.	68.3	59.0	33.2	49.8	16.3	23.4	—
Shaunavon	1943	69.2	64.4	20.5	27.4	18.2	25.1	8.3
	1944	60.6	54.0	9.9	12.4	2.7	16.8	8.4 and 4.6
	1945	71.4	71.5	7.4	26.7	18.4	42.8	5.7 and 7.7
	Av.	67.1	63.3	12.6	22.2	13.1	28 2	—
Riverhurst	1941	50.6	50.4	15.4	25.4	18.7	41.5	12.2
Consort	1941	40.8	34.5	9.2	15.8	9.8	7.4	11.2
Brandon	1942	47.3	45.8	28.4	37.7	15.2	13.8	13.2
Average all stat.		57.1	49.6	18 5	29.4	12.6	22.0	—

[1]Where two values are given the first refers to vulgare varieties, the second to durum varieties.

Among the durums, Golden Ball was the most resistant (Table 3). This variety is solid-stemmed and had the greatest sawfly resistance of any wheat tested in these investigations. Melanopus and Sivousska 3 approached Golden Ball in resistance. These varieties are not solid-stemmed. Among the other varieties tested the differences were small. There is a suggestion that Stewart is somewhat more susceptible than the rest, but further data are needed before this can be verified.

The hollow-stemmed durums as represented by Mindum were much more resistant than the hollow-stemmed vulgares (Table 3). The difference between the hollow-stemmed durums and the solid-stemmed vulgares varied greatly from test to test, but on the average Mindum was slightly more susceptible than S-615 and slightly less so than S-633.

EFFECT OF ENVIRONMENT

An examination of the data in Table 4 shows that the varieties differed in the amount of damage sustained during the same year at different stations, and during different years at the same station. The data were not considered sufficiently extensive to warrant a detailed study of these variations in relation to environmental factors, but an attempt was made to relate the differences to various weather data in order to see if any simple associations existed.

Seamans (18) found that weather conditions which produce a normal crop are most favourable for the sawfly. High rainfall or extreme drought resulted in fewer stems being cut. His observations were made on sawfly susceptible vulgare varieties. The results obtained in the present investigation were similar. Apex showed relatively small damage values at Scott in 1942 and 1944 (Table 4); both years were characterized by above normal precipitation. A similar situation occurred at Regina in 1942. On the other hand at Nobleford during 1943 and 1944 extreme drought conditions prevailed and again Apex showed relatively little damage. During seasons of high rainfall when plants are rank and succulent there is a high mortality among the larvae. This agrees with the observations previously made by Seamans (19). In addition it was noted, particularly at Scott in 1942, that the more or less continuous wet weather during ripening kept the base of the stems green and moist. Many of these stems, even though girdled by the sawfly, failed to fall over. In years of extreme drought the period between oviposition and the maturity of the crop is very short; presumably feeding conditions are poor due to lack of moisture in the stems and the high temperatures may be unfavourable to the larvae. Under such conditions larval mortality is high and damage decreased.

The reactions of the solid-stemmed vulgare varieties as exemplified by S-615 did not follow the pattern of Apex. Very probably the same factors were exerting their influence but other factors were masking the effect. Because light has been shown to affect the degree of solidness, and presumably the resistance, exhibited by solid-stemmed vulgare varieties, the percentage cutting in S-615 was correlated with hours of June sunshine. The negative value of 0.370 obtained was not significant (N = 18). That light can be an important factor is indicated in the results from Regina in 1945. In this test S-615 was cut 73% which was by far the greatest damage recorded for this variety under field conditions. At the same time there was some 60 hours less sunshine in June than in any other test on which records are available. It is possible that the low value of the correlation obtained may be due to lack of variation in light. With the exception of the test cited the hours of sunshine varied from 207 to 280. It would seem reasonable to suppose that after a certain minimum is reached further light would have little or no effect. If that minimum is in the neighbourhood of 200 hours then the variations in cutting that occurred are due to other causes. These could be the general effect of temperature and moisture and other factors that have not yet been investigated such as the nutrition of the plant and the sawfly.

The solid-stemmed durum, Golden Ball, retained its resistance under most conditions but even this variety showed considerable susceptibility in some tests. All durums tended to show high resistance under good

growing conditions. The coarse heavy stems produced under these conditions frequently failed to break over even when girdled. Under dry conditions resistance was sometimes high and sometimes low. No explanation suggests itself for the variations in cutting which occur during dry seasons.

The variability in reaction to damage is an interesting phenomenon. It also complicates the testing of hybrid lines. Further research may elucidate all the factors involved and make the interpretation of results of tests much simpler. However, it will probably be a long time before the breeder can determine the sawfly reaction of a hybrid line in a single test with the same accuracy as he can determine its stem rust reactions.

DISCUSSION

Despite the variability of the results it has been established that such solid-stemmed vulgare varieties as S-615 have a high degree of resistance to sawfly at most stations. In considering the damage sustained by this variety it should be kept in mind that the nurseries were located and handled in such a way as to obtain maximum damage. Only in exceptional conditions would a variety be subjected to such severe conditions under normal farming practice. That the resistance of S-615 can be transferred to agronomically desirable varieties seems highly probable (unpublished data). If this can be accomplished, immediate and substantial decreases in wheat losses may be expected. There remains the possibility that these decreases may not be permanent. In the first place there may exist physiologic races of sawfly to which such varieties would be susceptible. Physiologic races in Hessian fly have been reported by Painter (13). No evidence of specialized races of sawfly has been noted in this investigation. Even at Nobleford, Alberta, where a race of parthenogenetic flies exists (Farstad (7)), the varietal reaction is not significantly different from that in other areas where both sexes occur in approximately equal numbers. Nevertheless it is possible that such races exist. As yet no satisfactory technique has been developed for testing collections of flies at one point. Until such a technique is developed it will not be possible to appraise fully the status of physiologic races in evaluating resistance. In the second place the wide use of a highly resistant variety might tend to select a more virulent race of flies capable of causing greater and greater damage to the host. With this possibility in mind the characteristics of fly populations grown in various varieties have been studied. The results will be presented in a later paper. While tabulations are not yet complete, it appears that none of the populations studied is outstandingly virulent.

The differences in susceptibility among the hollow-stemmed vulgare varieties are not likely to be of any practical significance in reducing sawfly numbers. However, they are of interest because they demonstrate that factors other than stem solidness are involved in sawfly resistance. In view of this fact and in view of the varietal differences among solid-stemmed varieties, the question arises as to how close a correlation exists between stem solidness and resistance. Practical difficulties prevented a detailed study of this problem. Once a sawfly has tunnelled a stem it is usually impossible to determine whether or not it was solid. However, no hollow-stemmed variety has been found to have a high degree of resistance and no

solid-stemmed variety to be completely susceptible. Therefore, it would appear that the association is sufficiently close to be useful in a breeding program. Thus, it appears possible to select with a fair degree of accuracy for sawfly resistance on the basis of stem solidness.

The resistance exhibited by the durums makes them a useful crop for combatting sawfly infestations. Their usefulness is restricted by the limited market for this type of wheat and by the fact that the high quality durum varieties now available are inferior to the best vulgare varieties in yielding ability. The possibility of utilizing durum resistance in breeding vulgare varieties appears to be poor.

NOTES ON TECHNIQUE

In 1941 and 1945 the plots were arranged according to a lattice design, the durums in a complete and the vulgare in a quintuple lattice. The efficiency of these designs was compared with that of randomized blocks. The results are presented in Table 5. They show that important gains in efficiency were obtained by the use of lattice designs in a number of the nurseries. Furthermore, this type of plot design is much easier to use than randomized blocks in making field plans where large numbers of varieties are involved. The occasional gains of efficiency together with the ease of designing tests more than compensate for the extra calculations involved.

TABLE 5.—EFFICIENCY OF LATTICE DESIGNS AS COMPARED WITH RANDOMIZED BLOCKS IN TESTING FOR SAWFLY RESISTANCE IN WHEAT VARIETIES

Station	Efficiency in percent.			
	Varieties of *T. vulgare*		Varieties of *T. durum*	
	1944	1945	1944	1945
Scott	110	100	208	100
Nobleford	111	103	—	133
Swift Current	100	110	108	103
Shaunavon	100	139	118	103
Regina	—	102	—	128

It was observed that the main culms of hollow-stemmed varieties tended to be more susceptible than secondary tillers. The reverse was observed to be the case with solid-stemmed varieties. It was felt that differences in rate of seeding might affect relative reaction to sawfly by changing the proportions of tillers to main stems. Accordingly the four varieties S-615 (resistant), Hy-4131 (moderately resistant), Regent (moderately susceptible) and Apex (susceptible) were grown at four Stations in 1944. Each variety was seeded at the rates of ½, 1, 1½, and 2 bushels per acre in a split plot replicated five times. The test at Nobleford was discarded because poor stands were obtained. At the other three stations, good stands were obtained and no significant differences in sawfly reaction between different rates of seeding were established. In these particular tests, growth was well above average with much more than normal tillering. Under drier conditions different results might have been obtained. Until

further evidence is obtained it is probably wise to seed varietal tests at approximately the same number of viable seeds per plot and at the regular rate of seeding for the area concerned.

The varietal tests reported in this paper were conducted in single row plots. The question arose as to whether one variety might not affect the reaction to sawfly of any adjacent variety because of differences in growth habit or other causes. In 1944 three varieties of durum and three of vulgare were grown in five row plots with the rows 1 foot apart at the four stations. Each variety was replicated three times and the durum and vulgare plots alternated. The sawfly damage of each row of each plot was noted. When the centre rows of the plots were compared with the outside rows (adjacent to another variety) no significant differences were found. These results indicate that one variety has no noticeable influence on adjacent varieties and that single row plots are suitable for varietal tests.

In conducting the varietal tests a good deal of local variation was noted. Local depressions or hummocks frequently gave very different results from the surrounding areas, even in places where these did not affect growth markedly. Where soil heterogeneity produced variable growth, sawfly damage was also variable. These variations made the estimating of damage more difficult and resulted in a loss of error control. As these tests were conducted on margins of fields, small hummocks of drift soil and dead furrows were numerous. Experience has shown that it is time well spent to choose as uniform a piece of land as possible and to prepare it carefully for seeding tests to determine sawfly resistance.

Permanent Testing Areas

At the present time there are many fields in any district within the sawfly area where varietal tests could be conducted with every assurance of obtaining maximum infestations. However, it is quite possible that with the introduction of resistant varieties or crops, or by changes in farming practices, sawfly numbers may be greatly reduced or their characteristics changed. From the viewpoint of research it seems desirable that certain small areas be set aside where adequate populations can be maintained. In 1941 a 3-acre plot at Swift Current was selected for this purpose. This area is surrounded by grassland, chiefly *Agropyron cristatum* (L) Beauv. for a mile or more in each direction. The plot was divided into narrow strips. It was cropped as a 2-year rotation of fallow and wheat. Every second strip that was in crop each year was seeded to Apex, a susceptible variety. The other crop strips were used for varietal testing or other purposes. Sawflies were introduced in small numbers in 1941 and by 1943 the population was large enough to completely infest all stems. Infestations of 100% were also obtained in 1944 and 1945. These results would indicate that it is possible to set up permanent testing areas on quite a small acreage. Similar testing areas are in the process of development at the Dominion Experimental Stations at Lethbridge and Scott. Difficulties may be experienced in maintaining testing areas either through crop failures or by an invasion of parasites. With this in mind it would seem very desirable that additional permanent testing points be established in the sawfly area as soon as possible.

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SUMMARY

The reaction of wheat varieties to sawfly damage was determined by field trials. Uniform testing nurseries were established at various points throughout the area infested by sawfly. Varieties were grown in single 10-foot rows replicated three, and, in later nurseries, five times. The nurseries were located adjacent to infested wheat stubble. The criterion of damage found most satisfactory was the average of two independent estimates of percentage of the stems cut. Using these methods highly significant varietal differences were established in 24 of the 28 nurseries seeded. Hollow-stemmed varieties of *T. vulgare* were generally susceptible, solid-stemmed varieties of *T. vulgare* and varieties of *T. durum* generally resistant. Varietal differences within each group were also established. The hollow-stemmed vulgare varieties suffered greatest damage under average growing conditions and least when subjected to heavy rainfall or extreme drought conditions. It is suggested that the reaction of solid-stemmed varieties is modified by rainfall, hours of sunshine, and probably other factors, the exact nature of which could not be demonstrated with the data available. Durum varieties had high resistance in wet years and variable reactions in others. The use of lattice designs increased the efficiency of the test in a number of cases. Different rates of seeding did not significantly affect varietal reactions. Single row plots appeared satisfactory as no evidence was obtained that any variety affected the reaction of an adjacent one. Testing points with a high degree of soil heterogeneity gave extremely variable reactions to sawfly. The advisability of establishing small, permanent areas where large sawfly populations may be maintained for experimental purposes is discussed.

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THE EFFECT OF SEED TREATMENT AND DATES OF SEEDING ON THE EMERGENCE AND YIELD OF PEAS[1]

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Garden peas are widely grown in Saskatchewan although not on a commercial scale. Serious trouble is not usually encountered in obtaining satisfactory field stands; however, from time to time our attention is drawn to plantings where the emergence is very poor. In this province, information on certain aspects of pea culture is limited and because of this the present study was undertaken.

The literature on testing of seed treatment materials is extensive, both in Europe and America. In general the wrinkled-seeded varieties have shown decided benefit from treatment but this is dependent in large degree on seed and environmental conditions. Reports on temperature, moisture and soil type in relation to seed decay have shown the importance of these factors on resultant plant stands. Walker *et al.* (8) refer to a good deal of the relevant literature and report their findings as to the effectiveness of 2% Ceresan and red copper oxide on smooth and wrinkled-seeded pea varieties. Baylis *et al.* (2) present data relating to the effects of soil temperature, moisture and seed treatment on the emergence of peas. The present study reveals general agreement with the findings of other workers, although the effect of planting date as reported here is at variance with much of the published literature.

EXPERIMENTAL METHODS

Field tests were conducted for three consecutive years, beginning in 1943, dealing with the effects of seed treatments and dates of planting on the emergence and yield of garden peas. In 1943, Laxton's Progress and Lincoln were used and in the two following years the latter variety was used exclusively. Planting was done at three dates in 1943 and 1944 and at four dates in 1945, commencing in the spring as soon as the soil was ready. The plots were on a different portion of the same field each year, on summer-fallow. The soil is classed as clay loam and has a moderately high moisture holding capacity. In 1943, seed treatments used were Semesan and Spergon; the following year, Ceresan and Arasan were added; and in 1945, Du Bay 1452F, which contains 7.7% ethyl mercury p-toluene sulphonanilide, was also included making a total of five treatments in that year. Rates of treatment expressed as a percentage by weight of the seed were as follows: Ceresan, 0.1%; Spergon, 0.2%; Semesan, 0.25%; Arasan, 0.2%; and Du Bay, 0.1%. Treatment was done not more than four days and not less than 2 days prior to planting in every case and the seed was sown with a Kemp V-belt seeder. Planting dates were as follows: 1943, April 26, May 7 and May 18; 1944, April 27, May 8 and May 24; 1945, May 3, May 15, June 4 and June 18. All tests were randomized and replicated in accordance with recognized field plot procedure and the results were analyzed statistically. Some of the seed samples were commercial, others

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were hand threshed from our own plots. Soil temperatures at seed level were kept in 1944 and 1945, and in 1943 soil temperatures at the 6-inch level as well as air temperatures are available. Records of rainfall are likewise at hand for each year. The emergence counts were taken only after sufficient time had elapsed for maximum emergence to have taken place. Yields were based on weights of unshelled green peas. In 1943, pickings were made at several intervals throughout the season but in 1944 and 1945, due to scant rainfall, it was found that two pickings from each planting separated by a 10-day interval accounted for practically all pods produced.

EMERGENCE DATA FROM FIELD TESTS

Effect of Seed Treatments

The emergence data obtained from field tests in 1943, 1944 and 1945 are presented in Tables 1 and 2. In Table 1 the effect of treatment on each seed sample is shown for each of the three years. The dates of planting were averaged and are not shown separately. In Table 2, dates of seeding are shown separately for each year. In the columns, "treated", the percentages refer to the average of all treatments used.

Table 1.—The effect of seed treatments on the emergence of garden peas

Treatment	Emergence					
	1943		1944		1945	
	Laxton's Commercial	Lincoln Commercial	Lincoln Hand-threshed	Lincoln Commercial	Lincoln Composite*	Lincoln Commercial
	%	%	%	%	%	%
Check	45.5	74.0	88.0	52.0	67.5	60.0
Semesan	74.0	78.5	88.5	81.5	78.0	78.0
Spergon	67.5	72.5	92.0	73.5	75.0	75.0
Ceresan			94.0	76.5	79.5	72.0
Arasan			92.0	72.0	78.0	72.5
Du Bay					71.0	71.0

* Composite sample composed of two-thirds commercial and one-third hand-threshed seed.

Table 2.—The effect of dates of planting on the emergence of untreated and treated garden peas

Year	Sample	Seed	Emergence							
			Date 1		Date 2		Date 3		Date 4	
			Check	Treated	Check	Treated	Check	Treated	Check	Treated
			%	%	%	%	%	%	%	%
1943	Laxton's	Commercial	81	88	32	58	24	66		
	Lincoln	Commercial	89	88	75	77	59	61		
1944	Lincoln	Hand-threshed	96	95	83	88	85	90		
	Lincoln	Commercial	82	89	47	74	27	64		
1945	Lincoln	Composite	82	82	76	82	53	78	58	63
	Lincoln	Commercial	75	83	66	75	47	71	53	65

Wide variability in the effect of seed treatments on different samples is evident in Table 1. This was particularly true in 1943 and 1944. In these years, the general level of emergence was widely different between the two samples used each year. The greatest improvement due to treatment occurs, of course, where the seed is for some reason low in vigour. In 1943 the Laxton's variety was not examined closely but in outward appearance it was reasonably good. In 1944 the commercial sample of Lincoln appeared almost as good as the hand-threshed sample. Careful examination, however, showed about 20% of the seeds had slight cracks and abrasions of the seed-coat. This is considered to be one cause of its poor performance. The analysis of the 1943 data showed Semesan to be significantly better than Spergon in giving a maximum stand of plants. In 1944 no one treatment was significantly better than any other although Ceresan and Semesan averaged slightly better than Spergon and Arasan.

In 1945 a general improvement is attributable to treatment. Table 2 shows that the increase was chiefly at the second, third, and to a lesser degree the fourth dates of planting. No significant differences were found between Ceresan, Semesan, Spergon and Arasan; however, the emergence of the Du Bay treated seed was significantly lower than that of Ceresan and Semesan but not significantly lower than the emergence of Spergon and Arasan treated seed. Thus in all three years there is a suggestion that the mercurial dusts Ceresan and Semesan are slightly better than the non-mercurials in promoting a maximum stand of plants. The data obtained from only one year's experimentation with Du Bay 1452 F, also a mercurial dust, probably do not warrant a statement as to its effectiveness at this time.

Effect of Moisture and Temperature

It is quite apparent from Table 2 that in the 3-year period the highest emergence, regardless of the condition of the sample, was at the earliest date of planting. There was, in general, a decline in emergence with each subsequent planting and, while this trend was not absolute, it was very striking. It was sharper in the untreated than in the treated seed; that is, the effect of treatment was to maintain good emergence at all dates. There was a very substantial difference between samples in their ability to emerge well at all plantings. Some samples fell off markedly at the second and third dates, while others showed only a small decline. Considering the entire emergence data, perhaps the most apparent trend is the reduction in emergence with each later date of planting.

In an attempt to explain the relationship between date of planting and emergence, two factors come immediately to mind; viz., moisture and temperature. It has been shown by numerous workers, among them Hull (4), Jones (6), and Baylis (1), that high soil moisture accentuates pre-emergence damping-off and thus reduces stand. Further, they report this to be worse at low than at high temperatures. Baylis makes the following statement, "Whereas the effect of soil temperature has been inadequately studied, more especially as regards the action of the various pathogens, it has become clear that soil moisture is the predominating factor; viz., the higher the soil moisture the more severe the disease." McNew (7) reports that in tests under controlled conditions at 58°, 67°, 76°, and 90° F., seed decay by

Pythium ultimum becomes less severe with each increase in temperature. With the foregoing observations and experimental results in mind, a study was made of temperature and rainfall in relation to the various dates of planting in 1943, 1944, and 1945. In Table 3, the effect of date of planting on untreated seed is shown for each of the three years. Samples 1 and 2 refer to Laxton's Progress and Lincoln respectively in 1943, and in 1944 and 1945 Sample 1 refers to the hand-threshed and composite samples of Lincoln respectively. Sample 2 in the two latter years is also the Lincoln variety and in both cases is commercial seed. The rainfall shown in Table 3 is for a period inclusive of two days before and six days after each date of planting.

TABLE 3.—THE EFFECT OF DATE OF SEEDING ON EMERGENCE OF PEAS

Year	Dates of seeding	Rainfall	Emergence	
			Sample 1	Sample 2
		inches	%	%
1943	April 26	0.48	81	89
	May 7	Nil	32	75
	May 18	0.15	24	59
1944	April 27	1.05	96	82
	May 8	Nil	83	47
	May 24	1.20	85	27
1945	May 3	0.24	82	75
	May 15	0.11	76	66
	June 4	0.13	53	47
	June 18	Nil	58	53

As pointed out by McNew and others, rainfall is most severe in depressing emergence if it occurs soon after seeding. In 1943 and 1945, spring precipitation was limited and none of the dates of seeding were followed closely by appreciable amounts of rain; however, there was always sufficient moisture to promote good germination.

In 1944, April precipitation amounted to only 0.26″, most of which fell on April 14. Following the first planting on April 26, rainfall of 1.32″ fell during the first three days of May. There was no further precipitation until May 17, 18 and 19 when 0.39″ was received. Thus the second planting made on May 8 was neither preceded nor succeeded closely by rainfall, yet the emergence particularly in the poorer sample was very severely reduced. On May 23 a heavy shower occurred in which 1.20″ of rain fell. Warm, sunny weather on the following day dried the soil sufficiently so that planting with the seeder could be satisfactorily accomplished. This was done on May 24, and no further rainfall of consequence is recorded until July 1. Whether this rain closely preceding the third planting had an effect in reducing the emergence is difficult to say. The emergence in the commercial sample shows a definite reduction from the second date, yet the second date showed an equally substantial reduction from the first date and rainfall both before and after that planting was lacking.

From field observations and study of the rainfall data, the writer is of the opinion that the decreases in emergence as the season advanced were little affected by deviations from satisfactory soil moisture. That excess soil moisture may be a factor in causing pre-emergence killing is not questioned. Greenhouse tests with controlled watering demonstrated this clearly. The point to be stressed is that in 1943, 1944 or 1945 the percentage emergence followed a fairly definite pattern, decreasing as the season advanced, and this could not be correlated with moisture conditions.

In an appraisal of soil temperatures, there appears to be reasonably good correlation between increasing temperatures and decreasing emergence. The temperature was lowest at the first date of seeding and in general increased as the season advanced. The emergence was highest at the first seeding and decreased as the season advanced. Table 4 shows the average emergence of the untreated rows at each planting and the average mean temperature for a certain period following each date of planting. These periods have been chosen arbitrarily and are intended to approximate roughly the germination phase of the seed. They are 10-, 8-, 6-, and 6-day periods for the 1st, 2nd, 3rd and 4th dates of planting respectively. The temperatures shown are air temperatures in 1943 and soil temperatures at seed level in 1944 and 1945. Figure 1 shows the emergence of untreated peas in percentage at each date of planting and the average mean temperature for a period following each date of planting.

TABLE 4.—THE EFFECT OF TEMPERATURE ON EMERGENCE OF UNTREATED GARDEN PEAS

Year	1st Date		2nd Date		3rd Date		4th Date	
	Emerg.	Temp.	Emerg.	Temp.	Emerg.	Temp.	Emerg.	Temp.
	%	°F.	%	°F.	%	°F.	%	°F.
1943	85	44.0	53	39.0	41	66.0		
1944	89	47.6	65	53.7	56	66.2		
1945	78	37.8	71	43.3	50	54.9	55	64.4

Table 4 and Figure 1 indicate a correlation between temperature and emergence but they do not suggest that it is a simple relationship. For instance, the greatest decline in emergence is at the second date of planting, and the temperature difference between the first and second planting is slight each year. In fact it was higher at the first than at the second date in 1943. In 1943 the temperatures reported are air rather than soil; however, comparison of air and soil temperatures at the 2½-inch level in 1944 and 1945 did not indicate wide differences. The air temperatures were frequently higher than soil temperatures on warm cloudy days, and on sunny days the reverse was true. In 1944 and 1945, the soil temperatures were on the average about 6° F. higher at the second than at the first date.

The results presented here dealing with temperature relations are at variance with those reported by Brett *et al.* (3), Hull (4), McNew (7), and others. They are, however, in line with tests carried out by Hutton (5) in Australia who found that the mean percentage field emergence varied from one planting to the next, the tendency being towards poorer emergence

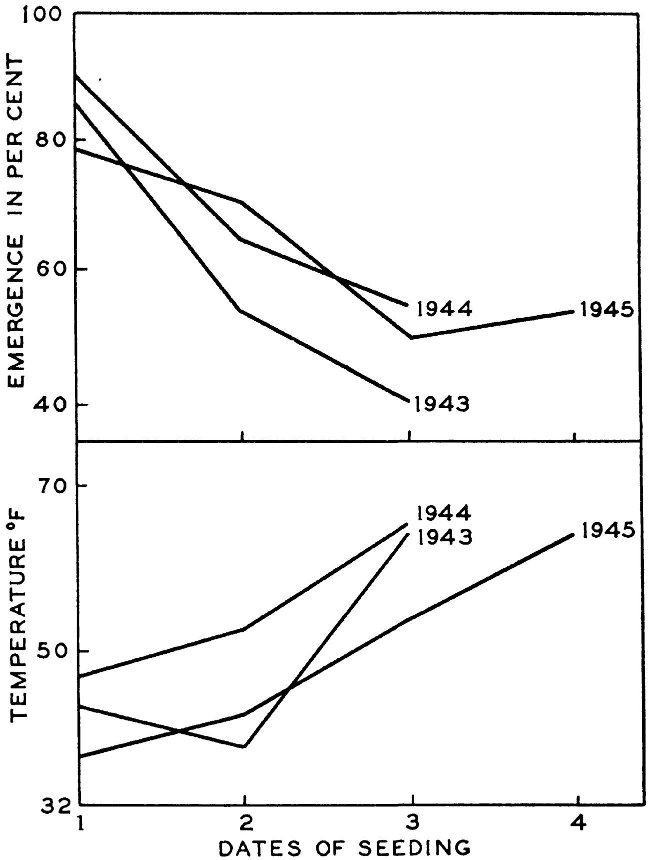

FIGURE 1. The relation between temperature and emergence of untreated garden peas. Air temperatures are shown in 1943 and soil temperatures at seed level in 1944 and 1945. They are the average mean temperatures for 10-, 8-, 6-, and 6-day periods following the first, second, third, and fourth dates of seeding respectively.

as the season advanced from cool spring to hot summer. The explanation of this differing response to temperature in widely separated geographic areas is not entirely clear. The main causal agent in pre-emergence blighting is reported to be *Pythium ultimum* in England and parts at least of the United States (1, 7, and others). No detailed study was conducted to identify the pathogens concerned in pre-emergence killing in the field work reported here. However, in greenhouse tests, peas in the untreated rows were dug up from time to time and examined. In most cases where germination was not progressing, the seed was surrounded by a dense mycelial growth. Isolations nearly always yielded a phycomycetous organism. Professor T. C. Vanterpool kindly examined two of these cultures, which he identified as *P. ultimum*. From this it appears quite possible that this is one of the important pathogens in Saskatchewan. Baylis *et al.* (2) found low temperatures such as would correspond to our first date of seeding to be favourable for pre-emergence blighting. But,

under our conditions, emergence was good at the first date. The writer suggests that in Saskatchewan the pathogens would be at a low ebb after the cold of winter and would require a certain period in the spring to initiate vegetative growth and increase to a more or less normal level. The first planting each year coming as soon as the soil was suitable for cultivation may have allowed the peas a period sufficiently long to pass the stage when they would be most susceptible before the fungi had increased appreciably. Further work is to be carried out to test the validity of this theory.

YIELDS IN 1943, 1944, AND 1945

Each year, yields of unshelled green peas were obtained. Several pickings from each date of planting were taken in 1943, but in the two following years rainfall was light and two pickings from each seeding date separated by about 10 days accounted for practically all pods produced. The 1943 yields, where the dates of picking were not kept separate, show that significant differences in yield were coincident only with large differences in emergence. Significantly higher yields in the treated rows were obtained in the variety Laxton's Progress at the second and third dates of seeding. It is generally known that in field tests where rainfall is a limiting factor the thinner stands, if not subject to weed competition, will often give as heavy a yield as the thicker stands of plants.

In 1944 and 1945, yields for the first date of harvest were two or three times as heavy as for the second date of harvest. The yields from the treated rows, at the first picking, were considerably heavier than from the untreated rows. This is more particularly true at the second and third planting dates where the stand of the untreated rows was reduced seriously. At the second date of harvest, the untreated rows gave the best yield. Table 5 shows the total yield in pounds from the untreated rows and the average of the total yields from the treated rows at each date of harvest. Also shown is the percentage increase or decrease in yield due to treatment.

TABLE 5.—YIELDS OF PEAS FROM UNTREATED AND TREATED SEED AND EFFECT OF TREATMENT ON YIELD

Year	Treatment	First harvest		Second harvest		Total yield	
		Yield	Percentage of check	Yield	Percentage of check	Yield	Percentage of check
		lb.	%	lb.	%	lb.	%
1944	Check	36.9		16.5		53.4	
	Treated	44.4	119.7	12.0	62.4	56.4	105.2
1945	Check	31.4		17.2		48.6	
	Treated	34.4	108.5	14.5	81.5	48.9	100.4

Total yields for the season showed no significant differences due to treatment either in 1944 or 1945, but at the first date of harvest the treated seed produced a significantly better yield than the untreated, while at the second date the reverse was true. It seems reasonable to assume that available moisture was the factor involved. Thus, the treated rows with their thicker stand of plants produced a heavier crop at the first date of harvest but in so doing they exhausted the soil moisture to a greater extent

than did the untreated rows. The untreated rows, due to their more favourable moisture reserve, gave a heavier yield than the treated rows at the second harvest.

GREENHOUSE TESTS

Two samples of peas were selected for a greenhouse temperature test in the fall of 1944. One was the wrinkled garden variety, Lincoln, and the other a round-seeded field variety, Dashaway; 35% of the kernels in the former variety showed injury to the pericarp in the form of slight fractures and abrasions, and in the Dashaway sample about 20% of the seeds were thus affected. Two hundred sound and a like number of injured seeds were selected from each sample. One-half of the sound and one-half of the injured seeds of each sample were treated with 5% Ceresan at a rate of 0.1% by weight. The peas were planted in duplicate, in beds in adjoining sections of the greenhouse, one bed maintained at an average temperature of 20° C. and the other at 8° C. The soil for both beds was taken from a well-mixed pile which was at a moisture level of approximately 48% of its moisture-holding capacity. The warm bed received a light watering four days after planting; and the cool bed, eight days after planting. Emergence in the former reached a maximum after 10 days; and in the cool bed, after 26 days. Table 6 shows the percentage emergence of the untreated and treated seed of each sample at each temperature.

TABLE 6.—EFFECT OF DIFFERENT TEMPERATURES ON EMERGENCE OF TWO VARIETIES OF PEAS IN THE GREENHOUSE

Sample	Condition	Emergence			
		20° C.		8° C	
		Check	Ceresan	Check	Ceresan
		%	%	%	%
Lincoln	Sound	64	94	80	92
Lincoln	Injured	6	70	48	66
Dashaway	Sound	60	82	40	72
Dashaway	Injured	18	42	6	40

In this test, seed treatment was very beneficial. Even in the sound seed, good increases may be attributed to it and in the injured seed the response was very substantial. The data also give evidence on a point which has been observed several times elsewhere; that is, the apparent different reaction of these two pea varieties to temperature. Lincoln peas have been shown to germinate best at low temperatures while Dashaway appears to give a better stand when the soil is warm.

A fairly extensive test was conducted in 1945 in which 10 samples of field peas, treated and untreated, were planted in the field. The emergence data from this test showed that every sample gave a much better stand at the second than at the first date of planting. It is realized that in a field test, variables other than temperature may enter into the picture so that several seasons' results supplemented by controlled tests in the greenhouse would be required to settle this point definitely. However, the results outlined here and supplemented as they are by limited greenhouse work are indicative that field peas of the variety Dashaway differ in their temperature relations to garden peas of the Lincoln variety.

DISCUSSION AND CONCLUSIONS

In field tests conducted in 1943, 1944 and 1945, garden peas were dusted with certain fungicides and planted in the field at several dates. Generally speaking, the emergence was best in the early sown peas and became progressively poorer with each subsequent planting. A decided benefit resulted from seed treatment at the later dates of planting and in the poorer samples. A number of studies dealing with the effect of seed treatment and soil moisture and temperature are reported in the literature. The findings are mainly in agreement that seed treatments are beneficial, their value depending on seed and environmental conditions. The data presented here indicate that the same is true at Saskatoon. In England and the United States of America, the cardinal factor in pre-emergence killing has been shown to be excessive soil moisture and, perhaps more particularly, rain soon after planting in its tendency to compact the soil around the seed, providing moist, poorly aerated conditions. Soil temperature has been given a minor role by English workers but in general they consider higher temperatures as being conducive to maximum emergence in garden peas. In the United States, McNew (7) found progressively less seed piece decay with each increase in temperature from 58° through 67° and 76° to 90° F. Dates of planting in the tests reported here have shown best emergence at the earliest date. The progressive decrease in emergence with each subsequent planting, particularly in the untreated rows, could not be correlated with changes in the soil moisture or with rain soon after planting. The temperatures from one planting to the next did, however, follow a more or less definite pattern, increasing as the season advanced. Scrutiny of the data suggests that the relationship between emergence and temperature is not a simple one. Possibly there is a delicate balance between soil temperature and the organisms causing pre-emergence blighting. The emergence data show in most cases an abrupt decrease between the first and second planting dates. The temperature during this interval changed only slightly on the average. It is suggested that *P. ultimum* and other organisms concerned in pre-emergence blighting require a period in the spring to initiate active vegetative growth. Early planted peas may have passed their susceptible stage before the fungi have increased sufficiently to cause much seed decay. The results reported here dealing with dates of planting are apparently in line with those of Hutton (5) in Australia who found a tendency toward poorer emergence as the season advanced from cool spring to hot summer.

In the matter of yield in garden peas, field results indicate little or no gain to be derived from seed treatment when the total yield for the season is used as a basis. However, the 1944 and 1945 tests show that the yields at the first harvest reflect fairly closely the thickness of stand; that is, the improved stands brought about by seed treatment outyield the thinner stands in untreated rows at the first date of harvest but the lighter stands did not use up available moisture as rapidly and so at the second harvest they were the heavier producers.

All of the treatments tested; i.e., Ceresan, Semesan, Arasan, Spergon, and Du Bay 1452F were effective, with perhaps some slight advantage in

favour of the mercurial dusts, Ceresan and Semesan. Du Bay 1452F in one year's trials and at one rate of application appeared to be slightly less effective than the others.

In a greenhouse temperature test, Lincoln peas, a garden variety, gave a better stand of plants at 8° C. than at 20° C., while with Dashaway peas, a field variety, the reverse was true. Likewise in one year's field trials, smooth-seeded field varieties emerged better at the second than at the first date of planting. These results suggest that the effect of temperature is at least in part on the host and that garden and field peas differ in their temperature requirements.

SUMMARY

Seed treatment of garden peas proved to be generally conducive to increased emergence and sometimes to increased yields at Saskatoon. The early sown peas emerged better than later planted ones, and seed treatment had its greatest effect on the latter. When total yields for the season were taken as a basis, only the severe reductions in emergence were reflected in reduced yield. However, yields at the first date of harvest were much more closely indicative of the emergence. In most cases, the treated rows produced heavier yields than the untreated ones at this date of harvest.

A comparison of emergence data with moisture conditions at the different dates of planting and with temperatures prevailing during the germination phase indicated that the emergence correlated fairly well with temperature but not with moisture. According to results presented here, soil temperature may be considered an important factor in determining the emergence of garden peas. Limited tests with smooth-seeded field pea varieties indicated that they were favoured by higher temperatures than were garden peas during their germination phase.

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THE RELATIONSHIP OF MOISTURE CONTENT AND YEAST COUNT IN HONEY FERMENTATION[1]

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Various authors have pointed out that there exists a relationship between moisture content and the fermentation of honey. The relationship, however, has never been established on the basis of yeast infection which is the recognized cause of spoilage. Consequently a statistical treatment of the microbiological and moisture analyses of honey samples from all producing areas in Canada has been undertaken to determine this relationship.

LITERATURE

Fabian and Quinet (2) suggested that the critical moisture content of honey is approximately 21%. Methods of determining the amount of moisture have changed and according to present tables in use their 21% is equivalent to 19.6%. Landerkin (3) states that the critical moisture content of honey is about 19%, while Lochhead (5) has illustrated how yeast and moisture content may be considered in predicting the length of time honey may be stored safely.

The author (8) has reported the relationship of moisture content and yeast count to the keeping quality of honey, based on observation of nearly 900 samples in storage. Some of these honeys had been heated during the extracting and canning process, and, since more recent work at the Bee Division, Central Experimental Farm, Ottawa, has revealed that even a mild application of heat has a lethal effect on honey yeasts, it has been necessary to reconsider the results. These and additional data have been treated statistically, and the present paper reports a correlation between moisture content and yeast count and discusses the relationship of these to fermentation and storage.

EXPERIMENTAL

Duplicate samples of honey representing a fairly even geographical distribution were obtained from the various producing areas in Canada. Records of source, treatment, and method of handling were obtained in each case. One set of these duplicates was stored at room temperature, while the other was used for physical, chemical, and microbiological analyses.

Storage samples were examined periodically for signs of fermentation, rate of granulation, and changes in physical condition. The corresponding samples were tested for colour, moisture, sucrose, invert sugars, nitrogen, other chemical components[3], and yeasts.

All honeys were tested for moisture content by the refractometer method. At first the refractive indices as prepared by Schönrock (7) were used, but, later, when Chataway's tables (1) became available, the earlier

[1] Contribution from the Bee Division.
[2] Assistant (Apiary products).
[3] For consideration of the changes in chemical constituents in storage see Progress Report of the Division of Chemistry, 1930–33, published 1935.

work was revised[1]. The grades used are those defined in The Fruit, Vegetable and Honey Act (10). The yeast counts on the 1929, 1931, and 1935 samples were made by the dilution method described by Lochhead and Heron (4), numbers being estimated according to McCrady (6). The crops of 1936, 1937, and 1938 were analyzed by the plate count method.

RESULTS AND DISCUSSION

Moisture Content and Fermentation

Table 1 shows the way in which the samples of honey were grouped according to moisture content, together with the number and percentage fermenting within a year in each group.

TABLE 1.—DISTRIBUTION OF UNHEATED SAMPLES OF CANADIAN HONEY ACCORDING TO MOISTURE CONTENT FOR SIX CROPS

Moisture	Samples	1929	1931	1935	1936	1937	1938	All years
%								
Under 15.1	No. of samples	15	10	2	22	5	8	62
	No. fermented	0	0	0	0	0	0	0
	% fermented	—	—	—	—	—	—	—
15.1–16.0	No. of samples	35	36	12	37	22	38	180
	No. fermented	1	1	0	0	0	3	5
	% fermented	2.9	2.8	—	—	—	7.9	1.8
16.1–17.0	No. of samples	67	32	24	54	42	61	280
	No. fermented	8	3	1	0	4	10	26
	% fermented	11.9	9.4	4.2	—	9.5	16.4	9.3
17.1–18.0	No. of samples	47	27	41	37	52	41	245
	No. fermented	17	19	8	6	21	28	99
	% fermented	36.2	70.4	19.5	16.2	40.4	68.3	40.4
18.1–19.0	No. of samples	13	17	20	14	25	11	100
	No. fermented	6	15	12	7	14	9	63
	% fermented	46.2	88.2	60.0	50.0	56.0	81.8	63.0
Over 19.0	No. of samples	4	3	10	9	14	5	45
	No. fermented	4	2	5	6	10	5	32
	% fermented	100.0	66.7	50.0	66.7	71.4	100.0	71.1
Entire range	No. of samples	181	125	109	173	160	164	912
	No. fermented	36	40	26	19	49	55	225
	% fermented	19.9	32.0	23.9	11.0	30.6	33.5	24.7

When plotted out (Figure 1) it is seen that percentage fermentation increases most appreciably in the region between 17 and 18%, falling off somewhat near the latter point and finally reversing direction beyond 19%.

The marked increase in fermentation in the 17.0 to 18.0% zone is of significance in the case of grading, as is evident in Table 2. The Fruit, Vegetable, and Honey Act (10) states that Grade I honey shall not contain more than 17·8% moisture; Grade II not more than 18.6%; and Grade III not more than 20%. Honey containing more than 20.0% of moisture is outclassed by the Food and Drugs Act (9), hence has been marked "Out" in Table 2.

[1] This fact explains the discrepancies existing between tables in the text and those published by the Bee Division and the Divisions of Bacteriology and Chemistry prior to 1935.

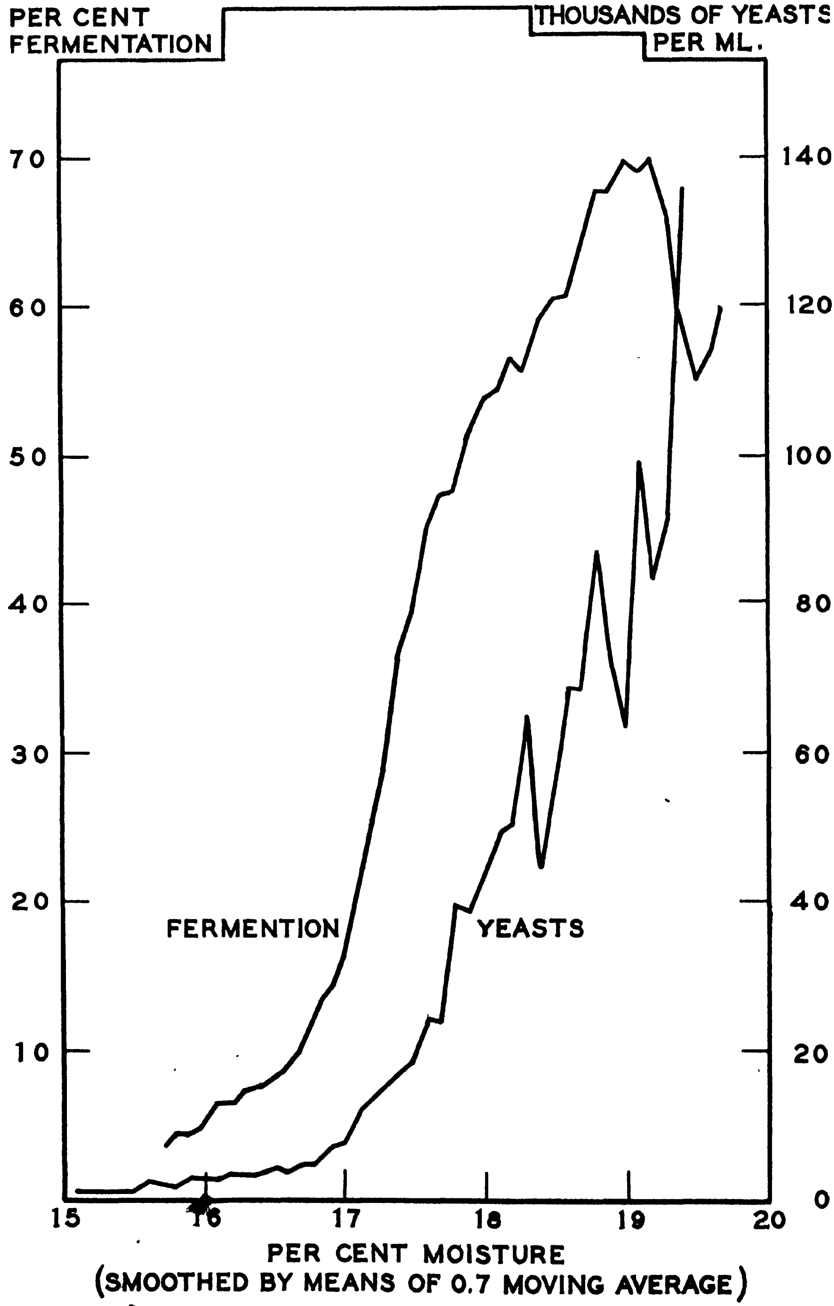

FIGURE 1. Relation of moisture content to yeast count and fermentation of Canadian honey.

TABLE 2.—DISTRIBUTION OF UNHEATED SAMPLES OF CANADIAN HONEY ACCORDING TO GRADE FOR SIX CROPS

Grade	Samples	1929	1931	1935	1936	1937	1938	All years
I	No. of samples	158	102	69	146	111	144	730
	No. fermented	23	20	6	5	20	37	111
	% fermented	14.6	19.6	8.7	3.4	18.0	25.7	15.2
II	No. of samples	14	18	24	9	25	15	105
	No. fermented	7	16	10	1	12	13	59
	% fermented	50.0	88.9	41.7	11.1	48.0	86.7	56.2
III	No. of samples	5	4	15	16	21	5	66
	No. fermented	2	3	9	11	14	5	44
	% fermented	40.0	75.0	60.0	68.8	66.7	100.0	66.7
Out	No. of samples	4	1	1	2	3	0	11
	No. fermented	4	1	1	2	3	0	11
	% fermented	100.0	100.0	100.0	100.0	100.0	—	100.0

TABLE 3.—FREQUENCY DISTRIBUTION OF UNHEATED SAMPLES OF CANADIAN HONEY ACCORDING TO MOISTURE CONTENT AND YEAST COUNTS

Moisture	Samples	Yeast count							Totals
		0.1 – 1.0	1.1 – 10	11 – 100	101 – 1000	1001 – 10000	10001 – 100,000	100,001 – 1,000,000	
%									
14.1–15.0	No. of samples	14	16	10	9	3	0	0	52
	No. fermented	0	0	0	0	0	0	0	0
	% fermented	–	–	–	–	–	–	–	–
15.1–16.0	No. of samples	31	17	38	42	26	4	0	158
	No. fermented	1	0	2	0	1	1	0	5
	% fermented	3.2	–	5.3	–	3.8	25.0	–	3.2
16.1–17.0	No. of samples	20	11	30	74	82	21	0	238
	No. fermented	0	1	1	9	10	1	0	22
	% fermented	–	9.1	3.3	12.2	12.2	4.8	–	9.2
17.1–18.0	No. of samples	12	5	19	35	58	55	9	193
	No. fermented	3	1	5	10	24	29	6	78
	% fermented	25.0	20.0	26.3	28.6	41.4	52.7	66.7	40.4
18.1–19.0	No. of samples	5	2	3	11	18	23	11	73
	No. fermented	0	2	3	6	13	15	10	49
	% fermented	–	100.0	100.0	54.5	72.2	65.2	90.9	67.1
19.1–20.0	No. of samples	1	0	0	1	5	8	7	22
	No. fermented	0	0	0	0	4	5	5	14
	% fermented	–	–	–	–	80.0	62.5	71.4	63.6
Entire range	No. of samples	83	51	100	172	192	111	27	736
	No. fermented	4	4	11	25	52	51	21	168
	% fermented	4.8	7.8	11.0	14.5	27.1	45.9	77.8	22.8

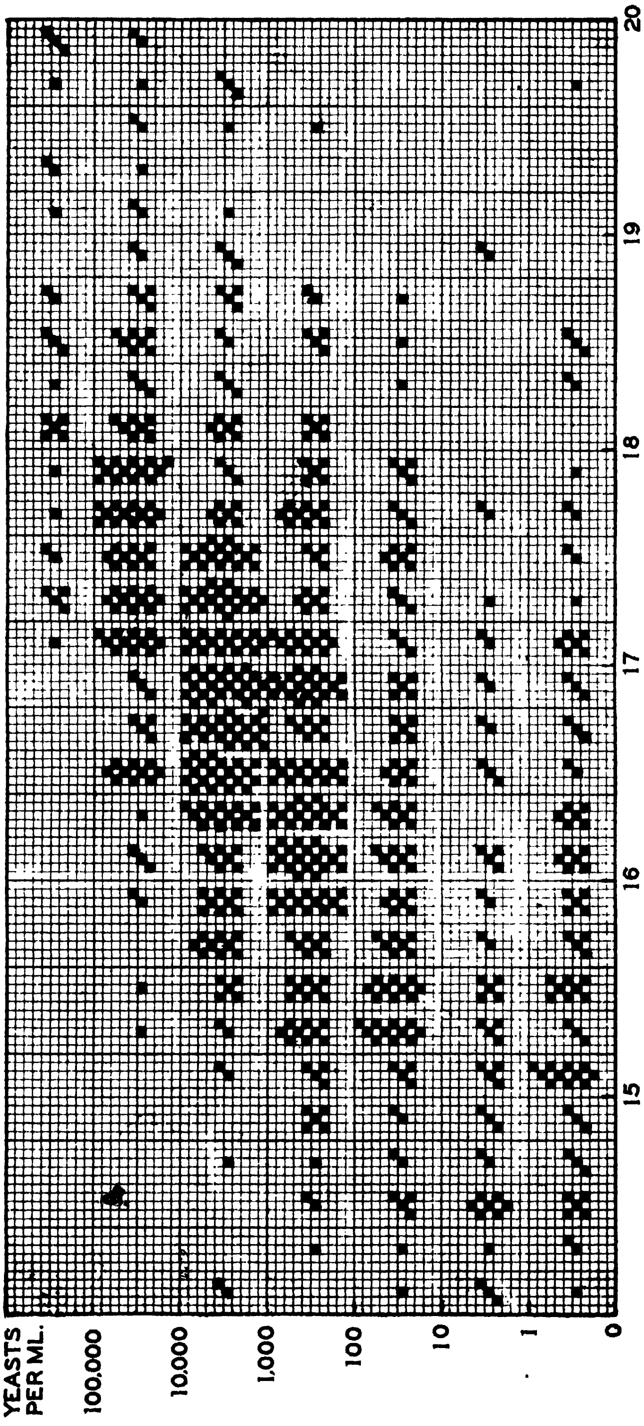

FIGURE 2. Yeast count of Canadian honey according to moisture content.

These tables show that approximately one-quarter of all the samples received fermented within the year and that in general the percentage of honey fermenting increases with increased moisture.

The reason fermentation does not occur as readily beyond 19.0% is explained by the fact that honey of higher moisture content crystallizes more slowly. The granulation of honey containing less than this amount of moisture has been observed to favour fermentation because of the moisture liberated when the dextrose forms crystals.

Moisture Content and Yeast Count

Table 3 presents the frequency distribution of 736 samples of the same honey arranged with class intervals of 1.0 logarithmic unit for yeast count and 1.0% for moisture. It has been necessary to decrease the number of samples dealt with in this section because of the uncertainty of the effect of heating the honey, to which earlier reference was made.

It is quite apparent that there is a definite relationship between moisture content and yeast count as indicated by the decidedly significant correlation of +0.50. Yeast count is plotted against moisture content in Figure 1. Higher moisture content, within limits, favours yeast multiplication and is therefore a potent factor in determining the number of yeasts in the honey, but other factors influence yeast counts also. This is obvious in Figure 2 which is a graphic presentation of data presented in Table 3.

On the basis of the data at hand for each increase of 1% moisture there is a corresponding increase of 4.81 times the original number of yeasts. The relation between yeast count and moisture may be expressed thus:— $\log Y = 0.6823X - 8.8562$, and by means of this equation Table 4 has been prepared. The lowest class was established by the mean yeast count found in honeys of 14.1 to 15.0%.

Table 4.—Predicted Yeast Count According to Percentage Moisture in Honey

Moisture	Yeast count	Moisture	Yeast count
%		%	
15	24	18	2,600
16	115	19	12,800
17	550	20	62,000

The predicted values in Table 4 are based upon the geometric means of the classes involved, whereas those indicated in Figure 1 are based upon the arithmetic means of the same classes. The distribution of yeast counts for any given moisture content is decidedly skew, so that the arithmetic means are greatly affected by a small number of very large counts.

SUMMARY AND CONCLUSIONS

A study on the relationship of moisture content to fermentation and yeast count has been carried out on over 700 samples of Canadian honey. Under laboratory storage conditions about 25% fermented within the year. Increase in fermentation of samples was greatest in honeys of 17 to 18% of moisture.

For each increase of 1% in moisture content yeast count may be expected to increase about 5-fold. Rate of increase in yeasts, in general, parallels rate of increase in fermentation.

Both yeast count and fermentation are influenced by the length of time which honey takes to granulate. Above 19% of moisture honey may not granulate as readily, thus influencing yeast growth and consequent fermentation.

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A COMPARATIVE STUDY OF CERTAIN PERFORMANCE AND CARCASS CHARACTERISTICS OF YORKSHIRE BARROWS AND GILTS[1]

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Investigators have reported that sex has an influence upon the performance and the carcass characteristics of swine. Lush (3) analyzed records from the swine testing stations in Denmark. He found that sex had an important influence on thickness of belly and thickness of back fat. He also discovered that sex had a significant influence on body length but found no significant sex difference in daily gains.

Crampton and Ashton (2) found a highly significant difference in rate of gain between the sexes. In feeding trials they found that male pigs gained 10 to 15% faster than females. Males required, on the average, a feeding period 14 days shorter than the females. They also found the carcasses of the females to be longer, to possess less fat over the shoulder and back, to have less thickness of belly, a larger eye of lean, and a higher percentage of lean in the rasher than did the carcasses of the males. They concluded from their study that, irrespective of ration fed, female carcasses graded higher, on the basis of present grade standards, than male carcasses.

Correlation coefficients for various carcass characteristics have been calculated by numerous workers. In nearly all cases, however, the computations have not been done separately for male and female carcasses. Nevertheless, the relationships which were found to exist are of interest.

Sinclair and Murray (6) found that there was no significant correlation between length of body and depth of back fat nor between body length and percentage shoulder. Lush (3) reported a strong negative correlation between body length and thickness of back fat. Stothart (8) found no significant relation between length of carcass and thickness of shoulder fat. He did find a significant negative correlation between length of body and area of loin muscle, and, also, between area of loin and thickness of shoulder fat.

Crampton (1) reported that rate of gain was not related to length of side nor to leanness of carcass. He also stated that length was not correlated with leanness. Crampton and Ashton (2) found that there was a significant correlation between gains and area of loin. They found that pigs that are older at time of slaughter have a larger area of loin.

The objective of this study was to obtain information that would be of some assistance in the interpreting of performance and carcass data of swine and particularly of swine of the Yorkshire breed.

MATERIALS AND METHODS

All data, from which the analyses reported in this paper were made, were obtained from the records of test groups of pure-bred Yorkshire swine that completed tests between May 1942 and February 1945 at the Advanced

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Registry Test Station at Saskatoon, Saskatchewan. Those animals in which sickness or disease had evidently retarded growth rate were not included in the analyses.

The pigs on which the study was conducted were handled according to the advanced registry testing plan. Full details of this plan, as well as the method of cutting and measuring the carcasses, are explained by Peterson (4) and by the Production Service, Department of Agriculture, Ottawa, Canada (5). The same operator was in charge at the Station throughout the observed period. Standard rations were fed and it is felt that environmental conditions were sufficiently constant to make unnecessary any adjustment for seasons, years, or rations.

It was originally thought that there would be a sufficient number of test groups made up of two males and two females for studies to be made on a paired basis. However, this was not the case. Only 37% of the groups that finished tests were actually made up of two males and two females, while 19% of the groups were made up of four pigs of similar sex. The information was, therefore, grouped according to sex and analyses made on a group comparison basis, according to the method outlined by Snedecor (7), rather than on an individual paired basis.

Simple correlation coefficients for certain performance and various carcass characteristics were calculated following the method outlined by Snedecor (7).

A total of 220 males and 181 females are included in that part of the study dealing with 70-day weights and daily rate of gains. In the carcass studies only those animals that were slaughtered within the live weight range of 198 to 207 pounds, inclusive, were used. This reduced the numbers in the carcass studies to 154 males and to 127 females.

RESULTS

PERFORMANCE AND CARCASS CHARACTERISTICS

The results of the study of certain performance and carcass characteristics are given in Table 1.

Male pigs were not significantly heavier than female pigs at 70 days of age. The larger daily rate of gain for males was, however, highly significant. Males attained a live weight of 200 pounds 4.34 days earlier than females, but this difference was just slightly under the level of significance.

Highly significant sex differences were found for all the carcass characteristics studied except for the difference in fat thickness. The difference in fat thickness is a measure of uniformity of the thickness of fat along the back. This difference is obtained by subtracting the minimum fat measurement, which was always over the back in the carcasses studied, from the maximum fat measurement, which was always over the shoulder. The carcasses from females did not have as great a thickness of fat as the male carcasses but the fat layer was just as uniform on the females as on the males.

Female carcasses were longer, heavier in the shoulder, lighter in percentage of middle, and heavier in the ham than were the male carcasses. Both males and females were much too heavy in shoulder, too light in

TABLE 1.—SUMMARY OF CERTAIN CHARACTERISTICS OF YORKSHIRE BARROWS AND GILTS

Characteristic	Mean Values		Pooled sums of squares	Difference in means	Standard error of difference in means	*t* value
	Male	Female				
70-day weight[1]	37.886 lb.	37.359 lb.	21,993 819	.527	.745	.707
Daily rate of gain[1]	1.280 lb.	1.234 lb.	9 5649	.046	.015	3.067‡
Age at 200 lb. live weight	198.10 days	202.44 days	94,657.8	4 340	2 207	1.966
Length of side	30.997 in.	31.338 in.	189.35	.341	.098	3.480‡
Thickness of shoulder fat	1.969 in.	1.798 in.	12.63	.171	.024	7.125‡
Thickness of back fat	1.101 in.	0 954 in.	9.13	.147	.022	6 682‡
Thickness of loin fat	1 529 in.	1.404 in.	12 17	125	.025	5.000‡
Difference in fat thickness (shoulder fat—back fat)	.873 in.	.850 in.	10.46	.023	.023	1.000
Percentage shoulder	27.228	27.646	266.27	.418	.117	3.573‡
Percentage middles	48.750	47 830	540.11	.920	.166	5.542‡
Percentage hams	24.028	24.506	205.38	.478	.102	4 686‡
Area of loin	5.092 sq.in.	5.870 sq.in.	227 62	778	.110	7.073‡
Total carcass score	76.448%	80.071%	25,039.00	3 623	1.135	3 192‡

[1] Degrees of freedom = 399. For all other items the degrees of freedom = 279.
‡ Significant at the 1% level of probability.

middle, and a little too light in ham to attain top bacon-type score. In balance of side, the males had a slight advantage over the females in scoring in that their lighter shoulders and heavier middles more than offset the larger hams possessed by the females. In no instance was there a carcass found which possessed the ideal balance of side, viz., 50% middles, 25% shoulder, and 25% ham.

The gilts possessed a very distinct and valuable advantage over the barrows in that the area of loin was larger. This, along with less thickness of fat on shoulder, back and loin, was largely responsible for the female carcasses scoring higher than did the male carcasses. This difference in carcass score in favour of females is similar, though not as large, as that found by Crampton and Ashton (2).

CORRELATION STUDIES

Simple correlation values were calculated for various characteristics. These values are shown in Table 2. Multiple correlations for these same characters were not calculated. No measure of the effect that inter-correlation or that the inter-dependence of the many characters would have on the apparent simple correlations was, therefore, obtained.

The weight at 70 days of age was positively and significantly correlated to the rate of daily gain for both males and females. This would suggest that the same factors, which are responsible for pigs attaining a large size at 10 weeks of age, continue to have an influence during the later life of the pig and until market weight is attained.

Both males and females showed highly significant negative correlations between length of side and thickness of shoulder fat. This finding agrees with the results published by Lush (3) but disagrees with the findings of Stothart (8), and Sinclair and Murray (6).

TABLE 2.—SIMPLE CORRELATION VALUES FOR VARIOUS CHARACTERISTICS OF BARROWS AND GILTS

Characteristic	Sex	Daily rate of gain[1]	Age at 200 lb. live weight	Thickness of shoulder fat	Percentage shoulder	Percentage ham	Area of loin
70-day weight[1]	Male	+.317†	—	—	—	—	—
	Female	+.161*	—	—	—	—	—
Length of side	Male	—	+.365†	−.456†	+.213†	—	+.085
	Female	—	−.108	−.231†	+.072	—	−.021
Age at 200 lb. live weight	Male	—	—	+.106	−.043	—	+.041
	Female	—	—	−.012	+.264†	—	−.014
Percentage middle	Male	—	—	—	+.259†	−.752†	—
	Female	—	—	—	−.476†	−.677†	—
Percentage shoulder	Male	—	—	−.079	—	—	—
	Female	—	—	−.397†	—	—	—
Thickness of shoulder fat	Male	—	—	—	—	—	−.047
	Female	—	—	—	—	—	+.018

[1] Degrees of freedom = 218 for males and 179 for females. For all other items degrees of freedom = 152 for males and 125 for females.
* Significant at the 5% level of probability.
† Significant at the 1% level of probability.

Barrows showed a positive significant correlation between percentage middle and percentage shoulder, while the gilts showed a negative and significant correlation between these characteristics. There was a fairly large and highly significant negative correlation between the percentage middle and the prcentage ham for both barrows and gilts. This would indicate that the desired balance of side will be difficult, if not impossible, to attain. As stated in the discussion following Table 1 of this paper, males and females were both lower in percentage middle and percentage hams than the level considered as the optimum percentage for these characteristics with ideal bacon type. Then, if the percentage ham regularly decreases as the percentage middle increases, it would appear to be impossible to achieve the desired percentages for these parts.

A significant negative correlation between percentage shoulder and thickness of shoulder fat and a significant positive relation between age at 200 pounds, live weight, and percentage shoulder was found among the females. No significant relationship was found among the males for these same respective characteristics.

The males showed a significant positive relationship between length and age at 200 pounds, live weight, and also for length and percentage shoulder while no significant relationship between these respective measurements was found among the females.

No significant simple correlations were found between area of loin and length of side, area of loin and age at 200 pounds live weight, area of loin and thickness of shoulder fat for either the males or females.

DISCUSSION AND CONCLUSIONS

The results of this study show rather conclusively that there is a considerable difference in the performance and carcass characteristics of Yorkshire barrows and gilts. Male pigs gain in weight faster than female pigs, and females attain a higher carcass score than do the males when both are scored according to the advanced registry scoring system. These differences are sufficiently large that it appears necessary, when testing litters to determine heredity differences, to have both males and females in the test group. If four animals are to comprise the test group it would appear desirable to have this group made up of two males and two females. When it is not possible to have both sexes equally represented, some adjustment for sex should be made.

The data also demonstrate that the weight at 70 days of age is an important item in determining later performance of both males and females. The larger pigs at 70 days of age will attain a live weight of 200 pounds before the smaller pigs because of two factors. In the first place they have a larger initial weight and do not need to gain as many pounds to reach the 200 pound weight. The second factor is that the heavier pigs have a higher daily rate of gain, on the average, than do the lighter pigs during the period from 70 days of age and up until market weight is reached. The influence of the 70-day weight is sufficiently important to make it necessary that the test animals from a litter be truly representative of the litter according to the 70-day weights of the individuals in the litter. If the test group from one litter were too heavy to truly represent the litter, while the test group from a second litter were too light to truly represent the 70-day weight of the litter, a bias would be introduced and the difference in heredity of the two litters would not be accurately compared.

The study also demonstrates that Yorkshire barrows and gilts, as represented by the animals used in this study, fall short of the ideal in balance of side. They were too light in middle and ham and too heavy in shoulder. Not a single individual was found that possessed the ideal balance of side. The results show, also, that the percentage ham decreases as the percentage middle increases. It would, therefore, appear to be impossible to attain the ideal balance of side through a system of selective breeding among Yorkshires such as those included in this study.

SUMMARY

Performance records of 220 male and 181 female, and carcass data on 154 male and 127 female Yorkshire pigs that completed tests under the advanced registry plan were analyzed.

There was no significant difference in 70-day weight between barrows and gilts but barrows had a significantly larger daily rate of gain.

Significant sex differences were found for nearly all carcass characteristics. Carcasses from females were longer, heavier in shoulder, lighter in middle, heavier in ham, and larger in area of loin muscle than were the carcasses from males. Both males and females were too heavy in the shoulder and too light in middle and ham for optimum bacon-type score.

Simple correlation values were calculated for various characteristics. A significant positive correlation between 70-day weight and daily rate of gain, a significant negative correlation between length of side and thickness of shoulder fat, and a rather large and significant negative correlation between percentage middle and percentage ham was found to exist for both barrows and gilts.

Sex differences in correlations were found for some characteristics. Males showed a positive correlation for some characteristics while females showed a negative correlation for these same factors. In other cases females showed a positive correlation for certain factors and males showed negative correlations for the same items.

It was concluded that sex differences in performance and carcass characteristics are sufficiently great to make it desirable to have small test groups of Yorkshire swine made up of equal numbers of males and females. It was also decided that, because of the influence the 70-day weight had upon later performance, the 70-day weights of the individuals in the test group should be truly representative of the 70-day weights of the individuals in the whole litter when it is desired to measure heredity differences of litters.

It was concluded, also, that it would be very difficult, if not impossible to attain the present ideal balance of side through a system of selective breeding among Yorkshire swine similar to the animals studied.

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TATTOO IDENTIFICATION OF SHEEP AND HORSES[1]

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A report (1) was published in 1940 on an investigation of certain phases of live stock tattooing. The majority of the large number of test animals of different species used in the investigation are no longer available for examination. However, a large proportion of experimentally marked sheep and horses remain and these have been inspected recently.

Since the trial period involved is a lengthy one and not easily duplicated, the information is reported here. The data, more especially with respect to sheep, are conclusive, and a practical application should benefit those breeders who have had unsatisfactory results in tattoo identification.

While the data obtained are from tests on two breeds of sheep and one breed of horses, it is considered that parallel results can be expected in other breeds and species.

SHEEP TATTOOING

In some breeds of sheep ear tattooing with black ink has not always provided permanent identification. Breeders have noted that, while a high proportion of animals of one breed retain a legible tattoo for long periods, other sheep which have been tattooed in the same manner may be very difficult to identify. In many cases tattoos become completely illegible which tends to discourage tattooing.

The causes, aside from the use of low grade materials or poor workmanship, appear to be due either to a thickening of the ear tissue or to naturally occurring darkly pigmented areas. In the latter case the dark patches of skin may be quite small at the time of tattooing but enlarge with maturity and, especially in older tattoos, make deciphering of tattoo symbols difficult.

COLOURED TATTOOS

To overcome these difficulties coloured tattoo compounds were formulated and tested on small groups of Southdown and Shropshire sheep. Two of these, which contained organic dyestuffs, proved to be non-toxic in a seven-month trial and showed a high colour retention. The ease of reading and high percentage legibility exhibited were so superior to black tattoos that tests on a larger scale were commenced.

After two years, the superiority of blue and green tattoos in both flocks was maintained. There was no apparent loss of colour intensity and all tattoos could be easily deciphered.

In the Shropshire flock, after five years, over 50% of the test sheep remained and these were given a final inspection. The reading of the coloured tattoos gave no difficulty. No diminution of colour had occurred since the original application and it was quite apparent that these tattoos would continue to be legible for the life of the animals. Neither special cleaning of the tattooed surface nor transmitted light were required.

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COMPARISON OF BLACK AND COLOURED TATTOOS

To illustrate the contrast between these results and previously observed black tattoos in the same flock, the data are summarized in Table 1.

TABLE 1.—PERCENTAGE LEGIBILITY OF SHROPSHIRE TATTOOS

Age of Tattoo	Black				Blue and Green	
	No. of tattoos	Legibility			No. of tattoos	Legibility—no treatment
		Before cleaning	After cleaning*	Trans-mitted light‡		
years		%	%	%		%
1	24 (12)	96	96	96	38 (19)	100
2	39 (20)	56	66	74	36 (18)	100
3	4 (2)	50	50	50		
4	24 (12)	50	66	66		
5	22 (11)	17	17	22	26 (13)	100
6	6 (3)	0	0	16		
7	2 (1)	0	0	0		
8	2 (1)	0	0	0		

* Ear surface cleaned by cloth dampened with carbon tetrachloride.
‡ Pen light behind and against tattooed area.
NOTE: The number of sheep examined at each period is indicated in brackets.

This comparison indicates that either green or blue tattoo compounds are more reliable than black. In addition the readability is enhanced.

These tests are considered to be conclusive in establishing coloured compounds as satisfactory tattooing mediums for the permanent identification of Southdown and Shropshire sheep. No other tests of these new tattoo formulas have been conducted but it would appear that they may have a wider application, not only in other breeds of sheep, but in other species of animals where colour contrast is desirable.

HORSE TATTOOING

Attempts to develop a tattooing technique that would provide positive identification and that would be applicable to all breeds of horses were commenced six years ago. While the trials were confined to the Clydesdale breed, it is considered that the results obtained may be applicable to many other breeds.

Due to circumstances, the number of animals on trial was less than desired for a test of this nature, but evidence has been obtained to show that horses, like other animals, may be individually identified by tattoo.

In approaching the problem many factors had to be considered, such as method of application, size of tattoo pliers and shape of needles, pigment concentration and viscosity, and optimum location for tattoo. A sufficiently long period has now elapsed to permit an assessment of the various factors involved. The conclusion has been reached that, with some modifications, the technique of tattooing used can be offered as a practical method for horse identification.

Tattoo Location

The area chosen for marking was inside of the lower lip, a location which offered a good contrast to black pigment. Healing takes place quickly here and there are the additional advantages of ease of application and inspection. Lip tattooing in the test horses caused no disfigurement and no apparent disturbance of feeding habits.

Since the mucous lining of a horse's mouth differs from skin structure previous observations on skin punctures would not necessarily apply. Hence the most effective shape and spacing of tattoo needles were investigated as well as the effect of depth of penetration. It was found that moderately shallow punctures are to be preferred. Penetration was controlled by the thickness of stripping pad used. Pointed needles are preferred to those with chisel shapes.

To counteract the expected interference due to excessive saliva, astringents and quick setting protective layers were tested. The former were used, both when incorporated in the formula and applied to the freshly made tattoo. However neither of these expedients was found to be a requirement.

Pigment Mixture

One of the most important factors in tattooing is the pigment mixture. It must have a sufficiently high concentration of pigment to ensure legibility and at the same time possess sufficient penetrating power. In addition the setting time of the compound must be such that, once applied, it will set quickly but not fast enough to interfere with handling operations. The best medium was found to be a black paste of about the same consistency as thick paint.

Tattooing Technique

The tattooing operation adopted is relatively simple and gives no particular difficulty in practice. Two persons are required. The horse is placed behind a wall or gate of convenient height and a twitch is applied to the upper lip.

The dies are placed in the pliers and tested for correctness by trying on a piece of paper. A rubber stripping pad is pressed down over the needles. An area on either side of the lip is wiped free of saliva and the tattoo compound placed on the dry area and on the tattoo needles. The tattoo is now made, very moderate pressure being required. The suggested location is approximately one inch from the lip margin.

With the lip held down a further quantity of compound is applied and rubbed well into the punctures. The lip is held down for a further fifteen seconds, to ensure setting of the compound.

The test group of horses did not include foals but experience in tattooing other animals shows that a young animal is a better subject for tattooing both from the point of view of management and results. Of the twelve horses remaining from the original group, eight had legible tattoos after a six-year period. The tattoos were viewed in daylight and legibility judged under those conditions, although it is known that doubtful tattoos can usually be deciphered by using transmitted light.

Observations made at the end of the test period indicate that astringents and protective coatings on the tattoo are not necessary. Since no deterioration in legibility occurred, it can be assumed that identification will be maintained for a further long period.

Modified pliers, having a deeper throat than the conventional type, would assist in a careful placement of the tattoo.

CONCLUSIONS

Coloured tattoos are permanent, more easily read and more reliable than black tattoos, in Southdown and Shropshire sheep.

Green and blue tattooing compounds are equally effective in the above breeds and are non-toxic.

Lip tattooing of horses requires:—

1. Concentrated paste form of tattoo compound.
2. Closely spaced, relatively short and pointed needles.
3. Attention to correct technique.

The individual identification of Clydesdale horses has been demonstrated. Lip tattooing is believed to be suitable for use on other breeds.

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PHOSPHORUS FIXATION STUDIES WITH SOME SASKATCHEWAN SOILS

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As is commonly known a considerable proportion of the phosphorus contained in fertilizers undergoes chemical change in the soil whereby the phosphorus is rendered relatively insoluble and unavailable to plants. This alteration of available phosphorus to unavailable forms is known as phosphorus fixation and constitutes one of the major problems in the use of phosphatic fertilizers. The extent to which fixation occurs varies considerably depending on the physical and chemical properties of the soil. No studies of the losses due to phosphorus fixation have been made with Saskatchewan soils but considering their great variations in physical and chemical properties it can be expected that there will be an equally large variation in their ability to fix phosphorus. Information concerning phosphorus fixation in Saskatchewan soils is needed in order to ascertain the fertilizer needs of the various soil associations and for the development of a sound program for fertilizer use.

The present study was undertaken to obtain information on the following points: (1) the rate and extent of phosphorus fixation in some typical Saskatchewan soils; (2) the effect of type of fertilizer used on the rate of phosphorus fixation; (3) the accumulation of nitrates as affected by soil type, addition of phosphate, and the presence of added nitrogen contained in the ammonium phosphate applied.

LITERATURE

The term phosphorus fixation has been used with different meanings. For the purpose of this study phosphorus fixation will be considered as a change of available phosphorus to a form not extracted by Truog's (23) solution as modified by Doughty (3). Truog (24) considers this to be a fair measure of the amount of phosphorus available to the plant. The phosphorus which is not extracted by this solution is considered to be in a difficultly available form.

The literature on the various aspects of phosphorus fixation is very extensive. A large number of papers deal with the various mechanisms of fixation and the various factors affecting fixation. These are best summarized in the reviews presented by Midgley (14) and Murphy (17).

Phosphorus fixation may occur by a number of different processes, depending largely on the pH of the soil. Chemical precipitation is the most important mechanism of fixation in calcareous soils, the soluble phosphates being precipitated as insoluble calcium and magnesium phosphates. McGeorge (10) states that in the presence of free lime a large part of these phosphates are converted to the carbonato-phosphate form which, due to its high potential alkalinity, is not readily rendered soluble by the action of plant roots. In acid soils phosphorus is fixed by chemical precipitation, mutual precipitation and by adsorption. Chemical precipitation is the result of ions of iron and aluminum combining with phosphate ions in

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solution forming insoluble compounds which are precipitated. However, Murphy (17) has pointed out that the soil solution is very dilute with respect to iron and aluminum ions and therefore contends that chemical precipitation of phosphorus from solution is negligible except in extremely acid soils. According to Metzger (13) mutual precipitation is one of the most important types of phosphorus fixation. This mechanism involves the precipitation of soluble phosphate on the colloidal surfaces of iron and aluminum hydrogels in the soil. Murphy (17) attributes a large portion of fixation to adsorption. The phosphate ions displace $SiO_3^{=}$ and OH^{-} ions from the crystal surfaces and become fixed in a form difficultly available to plants.

FACTORS AFFECTING FIXATION

Of the numerous soil properties that affect the extent and mechanism of phosphorus fixation, soil reaction is probably the most important. Murphy (17) has shown that maximum fixation due to chemical precipitation caused by iron and aluminum ions in solution occurs below pH 5.0. Scarseth (20) has shown that mutual precipitation is greatest at pH 3.7 with a slight decrease at pH 3.3 and a rapid decline above pH 5.5. He found increasing fixation by adsorption from pH 5.0 to 6.5 followed by a decline until no phosphorus was fixed at pH 7.5. At pH's above 6.5 phosphates become increasingly insoluble in the presence of calcium by forming tri-calcium phosphate or the more insoluble carbonato-phosphate.

The effect of $SiO_2 : R_2O_3$ ratio on phosphorus fixations has been studied by a number of workers. Scarseth (20) and Murphy (17) have concluded that with decreasing $SiO_2 : R_2O_3$ ratio there is usually increased fixation of phosphorus.

The effect of the degree of base saturation on a soil's capacity to fix phosphorus has been studied by Heck (6). By increasing the amount of exchangeable bases to give 90% base saturation he substantially reduced the amount of phosphorus fixation. He also found that increased base exchange capacity tends to decrease phosphorus fixation provided that the proper degree of base saturation is maintained. Heck's (6) data indicates that the degree of base saturation giving minimum fixation will be obtained at a lower pH if the organic matter content of the soil is high. It follows then, that soils of high organic matter content will fix less phosphorus than a similar soil of low organic matter content. Dunn (4) suggests that organic matter reduces phosphorus fixation by coating the mineral surfaces concerned thus preventing fixation, while Mattson (12) suggests that humate ions may displace adsorbed phosphorus from mineral surfaces. In any case it may be concluded that organic matter is effective in reducing the amount of fixation even though the reason for this is not definitely known. McGeorge (10) states that in calcareous soils organic matter is important in maintaining a supply of available phosphorus. He attributes this to the solvent action of carbonic acid which results from organic matter decomposition.

Physical conditions that affect chemical equilibrium also have an influence on phosphorus fixation. Time is an important factor; Heck (5) found that the period required for fixation under field conditions ranged from one month to a year. Robinson (18) showed that the rate of fixation increased with temperature, but this has little practical significance. The

effect of the soil-water ratio is more important. Hibbard (8) states that, in the field, from several months to a year may be required to fix phosphorus from applied fertilizer in clay soils. In a 1 to 1 soil-water mixture he obtained maximum fixation within an hour.

Hibbard (8) attempted to show the effect of different phosphate salts on fixation but his results are not conclusive. However, his work indicates the desirability of determining whether or not different phosphate fertilizers have different fixation rates when under the same conditions.

Although the causes of phosphorus fixation are now fairly well understood, the minimization of fixation in the soil is still a major problem. Some progress has been made in reducing fixation by the use of improved fertilizers and by better cultural practices. Many present day manufacturing processes granulate fertilizers in a form, which, it is hoped, will reduce the rate of phosphorus fixation. Hockensmith *et al.* (9) found that favourable placement of fertilizers greatly increased adsorption of phosphorus by plants. Liming and incorporation of organic matter into the soil are cultural practices which have been found to reduce phosphorus fixation. Spencer and Stewart (22) showed that some organic phosphates were not fixed by the soil. Such compounds eliminate loss of applied phosphate and fertilizers of this type may eventually be generally available.

METHODS AND MATERIALS

This project has been divided into two phases, the first consisting of laboratory studies and the second consisting of greenhouse studies.

Soils Used

The four soils selected for this study are similar in parent material. The Lloydminster, Oxbow, and Yorkton soils are from the black soil zone and differ mainly in reaction of their surface horizons. The Loon River soil is from the grey (podzolic) soil zone and was selected as a representative of the podzolic soils of the north-west portion of Saskatchewan.

The Lloydminster Association is not extensive in Saskatchewan but covers a considerable area in Alberta. These soils have a deep black solonetzic profile, and are developed on dark resorted boulder clay with a moderate lime content.

The Yorkton Association is extensive in Saskatchewan, occupying an area of almost two million acres. This soil usually has a deep black high lime profile only weakly developed and often containing calcium carbonate to the surface. The parent material is a calcareous resorted boulder clay.

The Oxbow Association is the most extensive one in the black soil zone occupying an area approaching seven million acres. This association is fully described by Mitchell *et al.* (15). The hard columnar profile is most common although solonetz and calcareous earth member profiles occur. The profiles are usually well developed, having a moderately black surface horizon, a hard columnar B horizon and a distinct lime layer. The parent material consists of undifferentiated calcareous boulder clay.

The Loon River Association constitutes a considerable area of the grey podzolic soils of north-western Saskatchewan. It is a deep podzolic soil developed on glacial till which is heavy sandy clay in texture and which has

very little free lime. The surface horizon has an A_0–A_1 layer ½″–2″ thick, while the A_2 is ashy grey and deeply leached. The B horizon is darker in colour and of hard columnar structure. No definite lime layer is found.

Laboratory Experiment

In the laboratory an incubation experiment was set up to determine the rate of phosphorus fixation in four soils and to ascertain the effect of the nitrogen carried by some of the fertilizers on the rate and extent of phosphorus fixation.

The soils used in this experiment were first dried and then ground to pass a 20-mesh sieve. The various fertilizers, after being pulverized, were added to the four soils at a rate equivalent to 50 p.p.m. of elemental phosphorus. After thorough mixing, ten samples of seventy grams were taken from each of the various treatments and placed in small sample bottles.

Duplicate samples of each of the different treatments were then set aside without incubation. The remaining samples were incubated at room temperature for varying periods. The incubation consisted of moistening the soils to approximately field moisture content, and maintaining them at this moisture level for the required incubation period. Duplicate samples were withdrawn from incubation after 3, 6, 9, and 24 weeks, dried and ground to pass a 100-mesh sieve. A portion of this material was then used in the determination of available phosphorus. The extent of phosphorus fixation for the different treatments and times was taken to be the difference between the amount of available phosphorus in the incubated sample and the amount in the non-incubated sample.

For the laboratory study four soils were used in conjunction with four different fertilizer treatments. The soils used were surface samples taken from summerfallow fields to the depth of five inches and were members of the Lloydminster, Yorkton, Oxbow and Loon River Soil Associations. The first three of these soils were selected because of their widely different reactions; the Loon River soil was selected for its low organic matter content and high $SiO_2 : R_2O_3$ ratio.

Fertilizers used in both greenhouse and laboratory studies were 11–48-0, 16–20–0, 0–38–0 and 0–38–0 plus NH_4NO_3. The 0–38–0 plus NH_4NO_3 fertilizer was prepared by blending pulverized 0–38–0 with sufficient ammonium nitrate to give the same ratio of phosphorus to nitrogen as is contained in 11–48–0. This has been designated in the tables as P–NO_3. All fertilizers were ground to pass a 100-mesh sieve to insure uniformity when they were mixed with the soil; this would insure maximum fixation under the conditions of the experiment.

Greenhouse Experiment

A greenhouse experiment using gallon crocks was set up having the same fertilizer treatments as were used in the laboratory experiment. Soils of the Lloydminster, Yorkton and Oxbow Associations were used in this experiment. The incubation periods were 0, 3, 6 and 9 weeks and were started at 3-week intervals, all being completed at the same time. After incubation, samples were taken for the determination of available phos-

phorus and prepared in the same manner as described for the laboratory incubation experiment. That portion of the samples not used for the determination of available phosphorus was retained for the determination of nitrates. Each crock contained enough soil to fill four shallow 6″ pots. These pots were sown to pre-germinated barley which was then grown for seven weeks. Distilled water was used to water the plants in order to avoid change in soil reaction due to the alkalinity of the tap water. The crop was cut in the shot-blade stage, dried and weighed. This weight was taken as a measure of the relative yielding ability of grain grown on the various treatments. The plant material was ground and analysed for phosphorus content in an attempt to correlate this with the supply of available phosphorus in the soil. After cropping, soil samples were again taken and prepared for the determination of available phosphorus.

Methods of Analysis

Available phosphate determinations were made using Truog's (23) solution as modified by Doughty (3). A photo electric colorimeter was used for phosphorus determinations according to the method described by Bertramson (1). Phosphorus fixing capacities of the four soils were determined by Heck's method (5). Phosphorus content of plant material was determined by the method of Shelton and Harper (21). Other chemical determinations were made by standard methods.

RESULTS AND DISCUSSION

Analytical Data for Soils Used

Results of chemical determinations made on the soils used in this study are given in Table 1. These data are closely related to the phosphorus problems of these soils.

As already mentioned the Oxbow, Lloydminster and Yorkton soils used in this study were selected because of the general similarity of their parent materials and because they differ widely in the reaction of their surface horizons. These soils from the black soil zone have $SiO_2 : R_2O_3$ ratios which are quite similar and which are considerably lower than the $SiO_2 : R_2O_3$ ratio for the podzolic Loon River soil. However, in the Loon

Table 1.—Analytical data for soils used
(cultivated surface horizon)

	Soil			
	Lloydminster	Oxbow	Yorkton	Loon River
pH	5.42	7.10	7.72	6.78
$SiO_2 : R_2O_3$ ratio	4.95	4.78	5.56	7.90
Organic matter, %	4.98	3.79	5.52	2.58
Total phosphorus, %	0.039	0.052	0.054	0.037
Available phosphorus, p.p.m.	24.8	50.0	63.2	18.8
Phosphorus fixing capacity, p.p.m.	105.2	55.5	23.1	18.0
Phosphorus fixed, p.p.m.	15.0	10.0	0	13.0
Total nitrogen, %	0.366	0.250	0.354	0.110
Nitrate nitrogen, p.p.m.	15.9	57.8	38.4	—

River soil the organic matter content is much lower than in the three black soils. The total phosphorus content of the Oxbow and Yorkton soils is lower than in similar Alberta soils while it is especially low in the Lloydminster and Loon River soils. It may be expected that the phosphorus rendered available by weathering in such soils will be less than in soils with a higher total phosphorus content. It is, therefore, probable that under cereal cropping the need for phosphatic fertilizers will be greater on soils such as these which have a low total phosphorus content than on soils with larger amounts of total phosphorus. The low content of available phosphorus in the Loon River and Lloydminster soils as compared with the Oxbow and Yorkton soils is probably a reflection of the differences in total phosphorus contents of the soils. The data for total phosphorus fixing capacity vary widely indicating very different properties in the soils concerned. However, these phosphorus fixing capacities are low when compared to some lateritic soils. Moser (16) has reported phosphorus fixing capacities as high as 400 p.p.m. The data for total nitrogen and nitrate nitrogen content indicate further differences in the soils concerned.

Laboratory Fixation Study

The amount of available phosphorus in each of the variously treated soils after the different periods of incubation is given in Table 2. The amount of added phosphorus fixed in an unavailable form can be calculated by subtracting the amount of phosphorus available after incubation from the amount available before incubation. The stability of the checks for

Table 2.—The influence of incubation period and kind of fertilizer on the amount of available phosphorus in four soils incubated in the laboratory

(Results expressed as p.p.m. available phosphorus)

Soil	Treatment	Incubation period				
		0 weeks	3 weeks	6 weeks	9 weeks	24 weeks
Lloydminster	Check	24.8	25.2	25.6	26.2	28.0
	11–48–0	65.5	49.6	50.2	49.4	50.0
	16–20–0	64.7	51.1	52.8	50.8	50.8
	T. S. P.	66.3	49.1	51.8	49.6	50.8
	$P-NO_3$	66.1	52.8	51.1	51.0	51.6
Oxbow	Check	50.0	50.2	52.8	53.0	53.2
	11–48–0	89.2	82.0	78.9	80.5	79.6
	16–20–0	89.2	79.2	79.8	80.3	80.5
	T. S. P.	90.7	79.9	79.6	80.4	81.0
	$P-NO_3$	88.2	79.9	78.3	78.4	79.3
Yorkton	Check	63.2	63.0	63.4	62.6	63.2
	11–48–0	99.8	99.4	100.6	100.7	101.0
	16–20–0	100.2	100.0	99.1	99.6	100.4
	T. S. P.	101.6	100.8	101.2	100.2	100.8
	$P-NO_3$	100.3	99.6	100.6	100.5	99.2
Loon River	Check	18.8	19.1	20.4	19.8	21.4
	11–48–0	57.1	44.1	44.0	43.4	43.3
	16–20–0	57.7	44.2	43.5	44.0	44.7
	T. S. P.	58.1	45.1	46.0	45.4	45.4
	$P-NO_3$	56.6	45.0	44.8	44.0	45.0

each soil over the 24 weeks of incubation shows that the soils, as taken from the field, were at equilibrium with respect to their content of available phosphorus. The slight increase in available phosphorus with incubation of the checks may be attributed to normal decomposition of organic matter and mineralization of phosphorus previously in organic form.

A sharp decline in the available phosphorus content of incubated soil is shown for all fertilized treatments on the Lloydminster and Loon River soils. This is true to a lesser extent on the Oxbow soil. The Lloydminster soil has fixed about 15 p.p.m. which is 30% of the applied phosphate. The Loon River soil fixed 13 p.p.m. while the Oxbow fixed 10 p.p.m., this being respectively 26 and 20% of the applied phosphate. The rapidity of fixation is rather notable; almost all of the fixation has occurred in the first three weeks with little change resulting from increased length of incubation period. This can probably be partly attributed to the intimate mixture of the fertilizer with the soil.

From the results of Table 2 it can be concluded that fixation of phosphorus in an acid insoluble form did not occur on the Yorkton soil. However, phosphorus may have been fixed in the form of tri-calcium phosphate or carbonato-phosphate. These forms would be redissolved in the acid extracting solution used for the determination of available phosphate.

There appears to be no difference in the amount or rate of phosphorus fixation due to differences in fertilizer treatments used on these soils.

Greenhouse Study

The data for available phosphorus determinations on greenhouse incubated soils is not given as these data were almost exactly the same as those in Table 2. The amount of phosphorus fixation in the greenhouse incubated soils was, on the average, very slightly less than occurred in the laboratory incubation. For example, Oxbow soil incubated in the laboratory for 24 weeks with 11–48–0 had 79.6 p.p.m. available phosphorus while after similar incubation in the greenhouse it had 82.0 p.p.m. available phosphorus. This may have been due to the maintenance of more uniform and optimum conditions of soil moisture during the greenhouse incubation. Furthermore, micro-biological activity was probably greater in the greenhouse incubated soils and this may have released phosphorus from organic compounds or have reduced fixation. Copeland and Merkle (2) have shown that lower phosphorus fixation occurs in the presence of actively decomposing organic matter.

The data for nitrate accumulation in the greenhouse incubated soils are given in Table 3. These results are introduced at this point so that their possible effect on crop growth may be pointed out. The Lloydminster soil shows the least nitrate accumulation for all treatments, while the Yorkton and Oxbow soils show about the same accumulation of nitrates. The greatest accumulation of nitrate in all cases occurs with the 16–20–0 treatment. The 11–48–0 treatment also shows a marked increase in nitrate over the check and has a larger percentage of applied ammonia converted to nitrate than is shown by the 16–20–0. However, as shown by Table 3, the 16–20–0 treatment had a considerably higher content of ammonia so that with it the actual amount converted to nitrate nitrogen was the highest of any treatment.

TABLE 3.—EFFECT OF FERTILIZER TREATMENT AND SUBSEQUENT PERIOD OF INCUBATION ON NITRATE ACCUMULATION IN THE THREE SOILS USED FOR POT EXPERIMENTS

(Results in p.p.m. of nitrate nitrogen)

Soil	Treatment	Incubation period				
		0 weeks	3 weeks	6 weeks	9 weeks	% NH_4 converted‡
Lloydminster	Check*	16.7	26.5	33.3	33.3	—
	11–48–0	16.0	39.5	44.0	44.2	41.6
	16–20–0	15.3	65.0	67.4	70.0	28.7
	T. S. P.	15.7	27.3	29.5	32.1	—
	P-NO_3	28.5	34.2	50.5	46.2	—
Oxbow	Check	57.5	72.0	78.4	70.6	—
	11–48–0	59.1	72.0	95.0	83.4	48.8
	16–20–0	57.0	119.3	110.3	111.1	43.6
	T. S. P.	57.4	67.7	75.1	67.3	—
	P-NO_3	70.8	88.3	85.0	74.9	—
Yorkton	Check	38.2	64.0	68.1	69.4	—
	11–48–0	38.1	53.4	79.7	85.3	56.8
	16–20–0	38.4	115.0	116.6	116.6	50.8
	T. S. P.	39.1	57.0	67.8	67.9	—
	P-NO_3	51.8	70.1	73.4	82.0	—

* NOTE: The amount of ammoniacal nitrogen in p.p.m. contained in the various fertilizer treatments was as follows: check—nil; 11–48–0, 26.2; 16–20–0, 93.0; T. S. P., nil; and P-NO_3, 13.1.

‡ The figures for % ammoniacal nitrogen converted indicate the % of applied ammoniacal nitrogen which has been converted to nitrate nitrogen during the 9 weeks' incubation period and are based on the assumption that nitrate formed from other sources was equal to the check.

For the three soils, the rate of nitrate accumulation is slightly lower on the 0–38–0 treatment than on the check. This may be explained by the greater activity of micro-organisms in the presence of sufficient phosphorus. The increased micro-organism population probably utilizes part of the nitrate in forming its own body tissues. All soils, especially those containing added ammonium carrying fertilizer, show a rapid increase in nitrate content during the first three weeks of incubation with a slower rate of accumulation thereafter. However, the maximum nitrate accumulation is reached on the Oxbow soil within six weeks followed by a decline. This occurs in all treatments on this soil including the check. Hedlin (7) obtained somewhat similar results, showing a decrease in nitrate accumulation after four or six weeks' incubation for a number of samples from the Weyburn Association. This decline is unusual and can perhaps be accounted for by the increased activity of micro-organism which accompanies incubation resulting in utilization of accumulated nitrates.

The data contained in Table 4 show the effect of fertilizer treatment and subsequent period of incubation on yield of barley grown for seven weeks on each of three soils. At the bottom of the table the necessary differences in yield required for statistical significance are given.

On the Lloydminster soil significant increases are obtained for all fertilizer treatments. The yield with 16–20–0 is especially high as is to be expected from the use under greenhouse conditions of a fertilizer high in nitrogen. The large response to 11–48–0 and 0–38–0 is, however, a good indication of the need for phosphate fertilizer in this soil.

Table 4 shows a significant decrease in yield as a result of three weeks' incubation for the fertilized treatments of the Lloydminster soil. Further decreases occur in the case of the 16–20–0 treatment and 0–38–0 with NH_4NO_3 treatment but they are slight compared to the original decrease for 3 weeks' incubation. Since no decrease in yield occurs as a result of

TABLE 4.—EFFECT OF FERTILIZER TREATMENT AND SUBSEQUENT PERIOD OF INCUBATION ON YIELD OF BARLEY GROWN FOR SEVEN WEEKS ON THREE DIFFERENT SOILS

(Mean values of four replicates in grams)

Soil	Treatment	Incubation period			
		0 weeks	3 weeks	6 weeks	9 weeks
Lloydminster	Check	5.48	5.43	5.24	5.34
	11–48–0	6.36	5.78	5.86	5.80
	16–20–0	7.22	6 74	6.55	6.60
	T. S. P.	5.88	5.63	5.66	5.53
	P-NO_3	6.91	6.59	6.50	6.37
Oxbow	Check	5.56	5.52	5.44	5.39
	11–48–0	5.94	5.77	5.90	5.91
	16–20–0	6.68	6.53	6.57	6 52
	T. S. P.	5.89	5.65	5.54	5.48
	P-NO_3	6.30	5.89	5.71	5.71
Yorkton	Check	6.02	6.23	6.55	6.54
	11–48–0	6.26	6.25	6.56	6.89
	16–20–0	6.71	7.24	7.36	7.52
	T. S. P.	6.22	6.26	6.64	6.78
	P-NO_3	6.46	6.84	7.16	7.40

Necessary difference in grams for significance at		*5% point*	*1% point*
Lloydminster	between treatments	.13	.17
	between periods	.11	.14
Oxbow	between treatments	.11	.15
	between periods	.10	.13
Yorkton	between treatments	.20	.27
	between periods	.17	.23

incubating the check treatment for 3 weeks, the decrease in yield, due to the same incubation of the fertilized soil, must be attributed to phosphorus fixation during the period of incubation.

The data show that the Oxbow soil responds to phosphate fertilizer, although the increases in yield are not as great as with the Lloydminster soil. There is a significant decrease in yield due to three weeks' incubation of all fertilized treatments. This decrease is attributed to phosphorus fixation which occurred during the incubation period. This conclusion is supported by results obtained from chemical analysis which shows a decrease in available phosphorus as a result of incubation.

Under the conditions of this experiment, barley on the Yorkton soil responds considerably less to applied fertilizers than it does on either the Lloydminster or Oxbow soils. The Yorkton check also has a much higher yield than the Lloydminster or Oxbow check. This is to be expected from the chemical analysis which shows the Yorkton soil to have a higher content of available phosphorus than either the Oxbow or Lloydminster soils. However, there is some response to added phosphate on the Yorkton

soil. In all treatments including the check, there is a significant increase in yield due to incubation. In some treatments this occurs as a result of three weeks' incubation, in other cases increases are shown as a result of six or nine week incubation periods. This is quite different from what occurred on the Lloydminster soil. If any phosphorus was fixed in the Yorkton soil during the incubation period then there were enough compensating factors to completely offset this effect. Part of the increase in yield may be attributed to nitrate accumulation during incubation. However, increased nitrate content occurred in the other incubated soils and still decreases in yield were observed. Another possible explanation is that offered by McGeorge *et al.* (11). They have shown that the solubility of phosphorus in calcareous soils above pH 7.6 can be increased by such incubation. This increase in phosphorus solubility is due to the action of CO_2 formed during the period of incubation as a result of micro-biological activity. The increased solubility of phosphate may have been an important factor in producing the increased yields which occurred on this soil as a result of incubation.

With the Yorkton and Lloydminster soils the triple superphosphate plus ammonium nitrate treatment consistently and significantly out-yields the ammonium phosphate 11–48–0 treatment which provides the same amount of nitrogen and phosphorus. This difference would seem to be due either to the nitrate content of the first treatment or to the difference in the chemical form of the phosphate contained in the two fertilizers. The data of Table 3 seem to discount the suggestion that these yield differences are due to differences in nitrate content of the soils. Therefore weight is added to the suggestion that the differences in yield are due to differences in the chemical form of the phosphorus contained in the two treatments. This is an important consideration and requires further investigation.

The need for added phosphorus in the soils used for this work is not only reflected in the yield but also in the composition of the plants. The results of some phosphorus determinations on the plants grown on the various fertilized and incubated soils are given in Table 5. The most

TABLE 5.—EFFECT OF FERTILIZATION AND SUBSEQUENT INCUBATION ON THE PERCENTAGE PHOSPHORUS IN PLANT MATERIAL

(Mean values of four replicates in per cent.)

Soil	Treatment	Soil Incubation Period			
		0 weeks	3 weeks	6 weeks	9 weeks
Lloydminster	Check	.263	.253	.261	.252
	11–48–0	.471	.518	.426	.474
	16–20–0	.449	.394	.402	.381
	T. S. P.	.510	.400	.488	.417
	$P-NO_3$	.454	.378	.456	.436
Oxbow	Check	.256	.258	.264	.301
	11–48–0	.571	.535	.555	.531
Yorkton	Check	.261	.247	.258	.242
	11–48–0	.467	.462	.486	.442

notable observation is the high phosphorus content of the plants grown on fertilized soil as compared to the check. This would have special significance where the crops grown are to be used on the farm for feeding live stock. Some of the increase in phosphorus content due to fertilization may represent luxury consumption by the plant. However, the large increase obtained would seem to indicate that the plants growing on unfertilized soil are in continuous need of additional phosphorus. A somewhat higher phosphorus content is found in the plants grown on fertilized Oxbow soil than on the other soils similarly treated. The more nearly optimum pH of the Oxbow soil for maximum absorption of phosphorus by the plant may account for this difference. No significant difference was found due to incubation of any of the treatments.

The acidic Lloydminster soil fixes applied phosphate to the greatest extent, the Oxbow soil fixes considerably less and the Yorkton soil fixes none as measured by the modified Truog solution used. The podzolic Loon River soil fixes more phosphorus than would be expected from its high pH, high $SiO_2 : R_2O_3$ ratio and low phosphorus fixing capacity. This may be attributed to its low organic matter content.

The importance of organic matter in minimizing phosphorus fixation in soils below pH 7 has been shown by Dunn (4). Addition of organic matter in conjunction with lime should reduce the fixing ability of the Loon River soil considerably. The increase in base exchange capacity and the saturation of the exchange complex with calcium or magnesium has been shown by Heck (6) to be of considerable importance in decreasing the amount of phosphorus fixed by a soil. This should be especially applicable to a highly leached soil such as the Loon River.

As indicated from the data contained in Table 1, Heck's (5) rapid laboratory determination of phosphorus fixing capacity is of doubtful value for Saskatchewan soils. The results obtained from the Lloydminster and Oxbow soils show the same relationship between phosphorus fixing capacity and phosphorus fixed under these experimental conditions. However the Loon River soil has a very low phosphorus fixing capacity yet fixes a large amount of phosphorus. The determination of the phosphorus fixing capacity of the Yorkton soil is likewise of little value. It appears that various factors are involved in phosphorus fixation in the field that cannot be duplicated in a rapid laboratory test. However the laboratory test may have considerable value when sufficient data are available to relate the results obtained to field results.

It is known that phosphorus requirements of annual plants are relatively heavy during the first few weeks after germination and again near the end of their life cycle while fruits and seeds are maturing. Under the conditions of the experiments reported here phosphate fixation was largely complete after three weeks of incubation. If the granulated phosphate fertilizers now commonly used are fixed with similar rapidity under field conditions, then fertilized cereal crops may lack available phosphorus in their final stages of growth. Should this be verified it would be desirable to try and develop phosphate fertilizers or fertilizing techniques which would insure the presence of adequate amounts of available phosphorus at the time crops are maturing.

SUMMARY

The rate and extent of phosphorus fixation were studied using various phosphatic fertilizers on four Saskatchewan soils varying markedly in reaction. Incubation experiments and greenhouse methods were used in conducting the study. The results may be summarized as follows:

1. By means of laboratory incubation work, using an application of phosphate fertilizers equivalent to 50 p.p.m. of elemental phosphorus, it was shown that the Lloydminster soil fixed 30% of the applied phosphorus while the Loon River and Oxbow soils fixed 26 and 20% respectively. The Yorkton soil showed no phosphorus fixation according to the method used. These results are broadly substantiated by results obtained from greenhouse experiments.

2. The type of phosphate fertilizer used or the nitrogen carried by the fertilizer did not influence the rate of phosphorus fixation as determined by the analytical method used. However, with the Yorkton and Lloydminster soils two fertilizer treatments supplying the same amounts of nitrogen and phosphorus, but in different forms, had consistent and significant yield differences when barley was grown. These yield differences may be a result of the difference in the chemical form of the phosphate used.

3. The reaction of the black zone soils was found to be the most important factor affecting phosphorus fixation, the greatest amount of fixation occurring in the most acid soils.

4. The high fixation found in the podzolic Loon River soil is attributed to its low organic matter content.

5. Maximum fixation occurred during the first three weeks of incubation.

6. Yield on calcareous Yorkton soil increased as a result of incubation. This is probably due to the accumulation of nitrates and to CO_2 production.

7. Plants grown on fertilized soil had a much higher phosphate content than those grown on the check.

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ASPARAGUS SELECTIONS AND CERTAIN CULTURAL PRACTICES COMPARED FOR YIELD, EARLINESS AND SEX RATIOS[1]

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Although considerable experimental work has been done on asparagus, no appreciable improvement has been made during the past twenty-five years. Opinion differs as to the advisability of grading roots at planting time and the discarding of small crowns. A project was begun at the Horticultural Experiment Station, Vineland, Ontario in an attempt to produce a higher yielding strain of Mary Washington asparagus and at the same time to investigate the effect of the size of the root at planting time on the subsequent yield of the plant.

LITERATURE

BREEDING

Hexamer (8) in 1901 noted that asparagus varieties lacked uniformity and suggested a method of seed production to maintain variety type by selecting typical high-yielding staminate and pistillate plants in the ratio of 1 male to 4 or 5 females. The following spring the selected plants were permitted to grow without cutting so that they flowered earlier than plants not selected and thus assured the crossing of the more desirable types.

Douglass (2) in Australia stressed the importance of selecting suitable staminate and pistillate plants and isolating them for seed production in the ratio of about 6 pistillate to 1 staminate. He further suggested that the seedlings obtained should be reselected on the basis of yield and type.

Schermerhorn (16), from records on approximately 1,500 asparagus plants, observed that some plants may not produce any spears or only 1 or 2, although others may produce over 100 spears. Some plants could be cut every day while others could only be cut every 2 or 3 weeks. There was considerable variation in the time of first harvest, some plants being cut early in the season, some in mid-season, and others very late in the season. He found that the diameter of the brush in the fall was not a reliable indication of the diameter of spears that may be cut the following spring.

Five year's records of individual asparagus plants as reported by Hanna (5) indicate a wide variation in yield, average weight of spear, cross-section, shape, earliness, compactness of head, and colour.

[1] Adapted for publication from a thesis presented to the Graduate School of the University of Minnesota by C. L. Thomson in partial fulfilment of the requirements for the degree of Master of Science.
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To obtain a high-yielding strain of asparagus Young (19) kept individual records on 278 plants for 2 years. Of the 10 highest yielding plants the first year, 5 were males and 5 females, and of the 10 high-yielding plants the second year, 6 had been in the high-yielding 10 the previous year. From this he concluded that it should be possible to obtain high-yielding parent plants which should produce high-yielding progeny.

From records on individual asparagus plants Robb (14) found considerable variation between plants. Some plants tended to be low-yielding and others to be high-yielding each season. A high correlation was shown between early yields and total yields.

Currence and Richardson (1), from 3 years' records on 250 plants grown from commercial seed of the Mary Washington variety, correlated yield and spear size with several other characters as a possible aid in making plant selections. There was a lack of correlation between size of 1-year-old roots and yield for the first 2 years of harvest. There was a significant correlation between early cuttings and yield of the 2 years. The number of stalks and the diameter of 4-year-old plants were significantly correlated with yield and spear size. Both of the correlations with spear size were negative. To obtain information regarding the transmission of yielding ability an individual female plant was crossed with 7 male plants. The production for 2 years on 4 progenies of 11 or more plants each, found 1 of the 4 progenies did not agree with expectations based on yields of the male parent which the authors felt was suggestive of the importance of progeny testing as an aid in selecting for high productivity.

At about the same time as the above work was being done Hanna (6), was attempting to discover how long individual plant records had to be taken in order to be certain of the yielding ability of the plant. He stated that "in general early yielding plants are frequently high yielding at the end of 4 years." On the basis of yields of 5 male plants for 7 years it appeared that 4 years was not sufficient time upon which to judge the yielding ability of the plants. Two of these plants showed a distinct increase in yield as they grew older, 2 others increased their yield slightly, while the remaining plant distinctly decreased in yield and the progeny of crosses of this plant also exhibited this tendency.

In a later paper Hanna (7) reports further data on 139 individual plants and shows correlations of total yields for the first 3 years, the first 5 years, and from the 6-to-8-year period. When all plants were considered, the yields at the end of the 3-year period and the 5-year period were highly correlated with the yield at the end of the 10-year period. This was also the same for the lowest yielding 20% of the plants. The highest yielding 20% showed a lower correlation for these same periods. There was a high correlation between 10-year yields and the 6 to 8-year yields for the high-and-the-low-yielding groups but a low correlation when all plants were considered. He found from the individual plant records that all of the high-yielding plants at the end of 10 years were not high-yielding during the early years and some of the high-yielding plants in the early years later died or were low-yielding at the end of 10 years. Data were also presented to show that in the selection of crowns at planting time neither the diameter of the crown nor the number of buds was a good indication of the future yield of the plant.

A later paper by Young (20) gives 5 years' data on 276 individual plants. He found a correlation of $+.913 \pm .065$ between average number of spears and the number of summer stalks and $+.817 \pm .013$ between yield and number of summer stalks.

Richardson and Currence (12) crossed 3 pistillate plants of similar phenotypic performance with 6 staminate plants 1 of which was phenotypically weaker than the others on the basis of 3-year records on weight, yield, number of spears per plant and average weight of individual spears. Fifty plants each of 18 progenies were grown in individual pots and weight records were taken $2\frac{1}{2}$ months after seeding. The progenies were compared as to number of days from seeding to emergence and weight at $2\frac{1}{2}$ months of age. The variation due to the interaction of staminate and pistillate plants was highly significant in regard to number of days to emergence and significant in regard to the weight of $2\frac{1}{2}$-months old progenies. The variation due to pistillate plants was significant with regard to weight of the progenies and that due to staminate plants was significant with regard to number of days to emergence. There was no significant correlations between any of the parental factors and those of their progenies.

It has long been recognized that astminate plants outyield pistillate plants. Robbins and Jones (13) found that during the first and second seasons of growth after transplanting, staminate plants outyield pistillate plants. They considered that the increased yield was due to greater food manufacturing surface of the staminate plant as compared to the pistillate. Currence and Richardson (1) were unable to show that the roots of staminate plants were inherently more vigorous, so they suggested that differences in production probably are the result of the formation of seeds by the pistillate plants. Haber (4) also found that male crowns produced a greater number of spears and heavier yield per plant than do females. Tiedjens (17) suggested that staminate plants outyield pistillate by 25% and that staminate plants die out sooner than pistillate plants. From a count of nearly 2,000 thirty-five-year-old asparagus plants Yeager and Scott (16) found a ratio of 3.5 staminate to 1 pistillate and they assumed that since the original ratio must have been close to 1 : 1 that apparently the pistillate plants died out sooner than the staminate. They also presented evidence that staminate plants outyield pistillate plants. Rawes (11) in England, from 3 years results, concluded that male plants yielded 60% better than females.

Robbins and Jones (15) investigated the possibility of secondary sex characters in asparagus, and while they were able to show that there were certain differences between staminate and pistillate plants, none of these would be of assistance in separating male and female plants before they flowered. They stated that "*Asparagus officinalis* is normally dioecious. All asparagus flowers are apparently potentially hermaphrodite. During floral development there is, except in rare cases, an abortion of 1 set of sex organs. The following flower forms occur; strongly pistillate, weakly pistillate, hermaphrodite, weakly staminate, and strongly staminate." They found only a very small percentage of true hermaphroditic asparagus plants during the course of the investigations. Norton (10) also found hermaphroditic flowers to be rare. Flory (3) also reported that the occurrence of hermaphroditic flowers was rare and that since these only occurred

on staminate plants suggested that the staminate plants were heterogametic for sex. Rick and Hanna (13) present data to indicate that in asparagus the staminate plants are heterogametic for sex and that sex is inherited in a simple Mendelian manner, maleness being dominant. The occasional seed produced on staminate plants is really the result of male selfiings which segregate in a ratio of 3 males to 1 female plant. A progeny test of the males will indicate those which are homozygous as they produce progenies of all male plants. Since male plants outyield female plants by a considerable amount, a method of producing an all male population would be very desirable. It was suggested that an isolated seed plot be established composed of high-yielding homozygous male plants, which had been determined by a progeny test, and high-yielding female plants. The seed produced from this plot would give an all male population.

Cultural Methods

It has been a general recommendation that asparagus growers should discard small crowns at planting time. Jones and Hanna (9) separated 1-year-old plants into 3 size groups at the time of planting and data on both spear and stalk production were collected for 12 years. They found no relation between size of crown planted and weight of spear or mean number of stalks per plant. The yield of the 3 crown sizes indicated the desirability of discarding the smallest crowns. In his investigations on effect of size of root at planting time on subsequent yield Haber (4) used 150-one-year-old asparagus plants dug in the spring. These roots ranged in weight from 3 to 57 grams. He found no correlation between the weight of crowns and weight and number of spears produced when male and female plants were considered together. There was, however, a significant correlation when only male plants were considered. Currence and Richardson (1) and Hanna (7) from their work suggest that the discarding of the small crowns may eliminate some of the highest yielding plants.

MATERIALS AND METHODS

For this experiment seed was obtained from 5 high-yielding postillate Mary Washington plants which had been isolated with 2 high-yielding staminate plants of the same variety. Individual plant records had been taken on these plants for 3 years by Robb (14). Seed of these 5 selected strains designated as strains 14, 35, 38, 40, and 44 and a commercial strain of the Mary Washington variety of asparagus was planted in the greenhouse in February 1933 and also outside in May 1933. The plants grown inside were transplanted outside at the same time and adjacent to the outside sown seed. Both sets of roots were planted in April 1935 in the permanent location where the soil is classified as Vineland Fine Sandy Loam. At that time the roots of the 6 strains were graded for large size and number of buds, approximately 40% being discarded from each strain. Strain 44 and the commercial strain were included as both graded and ungraded roots. The 6 strains with graded roots and the 2 strains with ungraded roots were considered as 8 different strains and were randomized in eight blocks. The main plots of strains were composed of randomized sub-plots of roots from inside and outside sown seed. A sub-plot consisted of a single row of 12 plants spaced 2 feet in the row and 4 feet between rows.

The first harvest was in 1937 for a period of 4 weeks. In 1938 the length of the cutting season was 6 weeks, in 1939 5 weeks, and in 1940 7 weeks. As far as possible the asparagus was cut when the spears were from 6 to 8 inches long and this usually required that harvesting be done every second day. The total weight of the spears cut from each plot was recorded in grams regardless of the size or grade of the asparagus. At the end of each year the total weight of the asparagus cut from each plot was converted from grams to tons per acre for ease in calculation.

RESULTS

The data were analyzed according to the analysis of variance and the essential information is given in Table 1. The F value for years exceeds the value necessary at the 1% point. It is to be expected that a perennial crop such as asparagus would show a progressive increase in yield as it advances toward maturity. For strains the F value was highly significant and for seeding time it exceeded the 5% point. The F value of 1.46 for the interaction of years and strains approaches the value of 1.64 necessary for significance at the 5% point.

TABLE 1.—ANALYSIS OF VARIANCE OF DATA ON YIELDS IN TONS PER ACRE OF ASPARAGUS RESULTING FROM DIFFERENT STRAINS AND TIMES OF SEEDING

Variation due to	D/F	Mean square	Standard error	F Value
Years	3	20.240817		30.37†
Strains	7	6.866753		13.38†
Replications	7	1.368608		2.66*
Error *(a)*	49	0.514121	0.7170	
Sub-total	53			
Seeding time	1	1.866070		4.77*
Seeding Time × strains	7	0.411288		1.05
Error *(b)*	56	0.391201	0.6254	
Sub-plots	127			
Years × replications	21	0.107887		1.25
Years × strains	21	0.125968		1.46
Error *(c)*	147	0.086504	0.2941	
	255			
Years × seeding time	3	0.016760		
Years × seeding time × strains	21	0.077865		1.10
Error *(d)*	168	0.070718	0.2659	
Total	511			

* Exceeds value for 5% point.
† Exceeds value for 1% point.

YIELDS OF SELECTIONS AND A COMMERCIAL STRAIN OVER A FOUR-YEAR PERIOD

The interaction of years and strains is presented in Table 2 and none of the cross differences was significant. The yields of the various strains remained rather consistent over the 4 years. The yields of the strains the

TABLE 2.—THE YEARLY AND TOTAL YIELDS OF SPEARS IN TONS PER ACRE FROM GRADED ROOTS OF 5 SELECTED STRAINS AND 1 COMMERCIAL STRAIN AND FROM UNGRADED ROOTS OF 2 OF THE SAME STRAINS OF MARY WASHINGTON ASPARAGUS

Strains	1937	1938	1939	1940	Total	Mean
14 Graded	1.92	2.15	2.86	2.74	9.67	2.418
35 Graded	1.96	2.02	2.66	2.85	9.46	2.365
38 Graded	1.83	1.55	2.17	2.22	7.47	1.666
40 Graded	1.67	1.93	2.69	2.65	8.94	2.235
44 Graded	1.33	1.67	2.18	2.19	7.56	1.890
44 Ungraded	1.68	1.87	2.20	2.31	8.66	2.015
Com. graded	1.34	1.57	2.01	2.12	7.04	1.760
Com. ungraded	1.02	1.21	1.78	1.80	5.81	1.452
Total	12.61	13.97	18.55	18.88	64.01	16.003
Mean	1.376	1.746	2.318	2.360	8.001	2.0003
Sig. Difference*	0.20	0.26	0.33	0.39	0.51	0.235

* Minimum difference required for significance at the 5% point.

first year were also closely in line with the total yields for the 4 years. This did not agree with the work of Hanna (7) who found a low correlation between the yields of individual asparagus plants at the end of 3 years and at the end of 10 years. However, this plantation seems to have reached peak production as indicated by strains 14, 40, and 44 which apparently attained maximum production at 3 years.

The yields of the 5 selected strains and the commercial strain as given in Table 3 indicate that these 6 strains may be divided in 2 groups on the basis of yield. The high yielding group of strains 14, 35, and 40 significantly outyielded the lower yielding group comprising strains 38, 44 and the commercial strain. Strain 38 which was the lowest yielding of the selected strains exceeded the yield of the commercial strain by an amount which approaches significance. Since 3 of the 5 selected strains significantly outyielded the commercial strain and the other 2 exceeded that strain by an amount tending to be significant there would seem to be little doubt that the yielding ability of the parent plants was to some degree at least transmitted to the next generation. The performance of the 6 strains in this test would tend to confirm the value of progeny testing as a means of selecting high yielding parent plants as suggested by Currence and Richardson (1). Richardson and Currence (12) working with small progenies found 1 plant out of 4 whose progeny did not agree with expectations based on the performance of the parents. The selected strains on the average exceeded the yield of the commercial strain by about 23% but strain 14, the best of the selected strains, outyielded the commercial strain by 37% or, where the commercial strain was not graded, by over 80%. These distinct differences in yield suggest that asparagus growers should be entitled to expect strains of asparagus which should outyield present strains by at least 50%. The evidence seems definite that while some improvement in asparagus can be expected by isolating superior phenotypes still greater improvement may result from the isolating of superior parent plants by means of the progeny test.

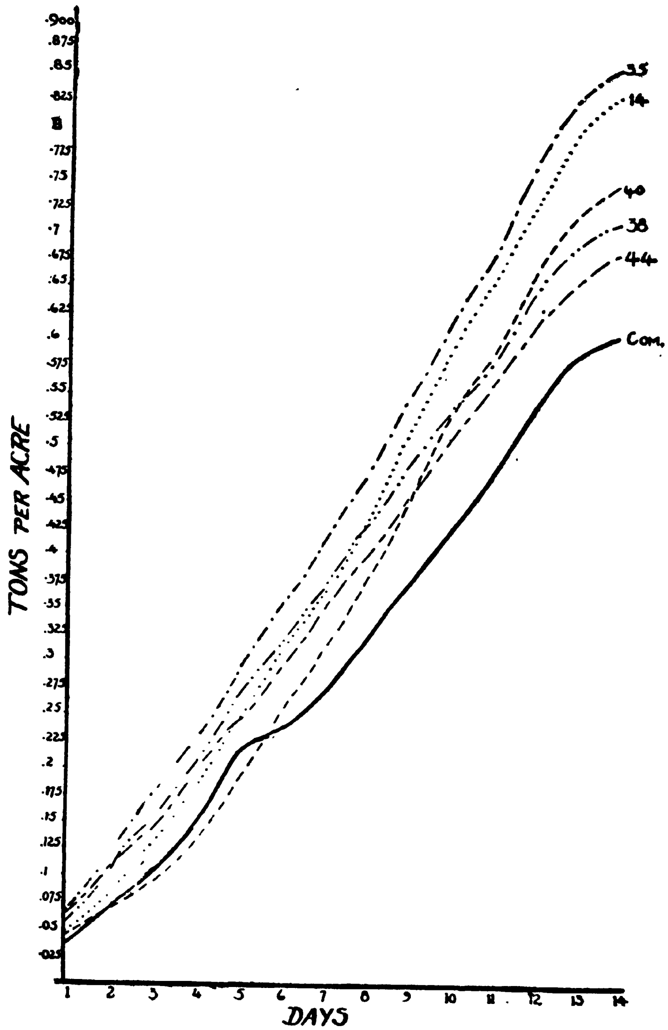

FIGURE 1. The 4-year average yield of 6 strains of asparagus for the initial one-third of the harvest season.

EARLY SEASON YIELD

Since the yield in the early part of the season is an important consideration for either the home or market gardener the 6 strains have been compared in regard to their yielding ability early in the season. The average yields for the 4 years of the 6 strains for the first 2 weeks or approximately the initial one-third of the harvest season are shown in Figure 1. Strain 35 appears to be outstanding as regards early yield as well as total yield and would appear to be more desirable than strain 14 which gave an almost equal total yield. Strain 40 ranked with strains 35 and 14 in total yield but the early yield was very poor. It is of interest that all of the

selected strains have a greater early yield than the commercial strain. While no attempt has been made to correlate early yield and total yield the yielding behaviour of the 6 strains in regard to early and total yields is reasonably similar. This is in agreement with the work of Robb (14) who found a correlation between the early and total seasonal yields of individual plants. While the differences in early yield shown in Figure 1 cannot be tested statistically for significance it would appear quite possible to breed early high-yielding strains. Since the strains having the highest early yield have also a high total yield, a strain or variety combining high early and total yield is an interesting possibility.

TABLE 3.—THE TOTAL YIELD IN TONS PER ACRE OF THE GRADED ROOTS OF 6 STRAINS AND OF THE UNGRADED ROOTS OF 2 OF THE SAME STRAINGS TOGETHER WITH THE PERCENTAGE OF MALE AND FEMALE PLANTS AND A X^2 ANALYSIS OF THE TWO SEXES

Strain	Yield	Males	Females	X^2	P
	Tons per acre	%	%		
14 Graded	9.57	53	47	1.333	0.3 - 0.1
35 Graded	9.46	46	54	1.905	0.2 - 0.1
38 Graded	7.47	48	52	0.424	0.7 - 0.1
40 Graded	8.94	46	54	1.347	0.3 - 0.1
44 Graded	7.56	45	55	2.105	0.2 - 0.1
44 Ungraded	8.06	45	55	2.105	0.2 - 0.1
Com. graded	7.04	52	48	0.266	0.7 - 0.5
Com. ungraded	5.81	40	60	9.186	<0.01
Mean	8.01				
Sig. difference*	0.51				

* Minimum difference required for significance at the 5% point.

ROOT GRADING AS RELATED TO YIELD

The yields of the graded and ungraded roots of strain 44 and the commercial strain are presented in Table 3. The difference in yield in favour of the ungraded roots over the graded roots of strain 44 was 0.50 tons while the minimum difference required for significance was 0.51 tons. The graded roots of the commercial strain significantly outyielded the ungraded roots of the same strain.

If the results of root grading with only strain 44 are considered the data suggest that root grading by discarding the small roots at planting time as a means of eliminating low-yielding plants, may not be justified. Currence and Richardson (1) did not obtain a significant correlation between the weight of 1-year roots and the yield over a 4 year period. Young (20) also concluded that even the most careful selection of roots at planting time would not eliminate poor producing plants. However, Jones and Hanna (9) showed that from 12 years' data with 2 varieties of asparagus, it was desirable to discard small crowns at planting time. In this experiment, the results would tend to suggest that it is desirable to grade the roots at planting time, but in view of the limited scope of the test, and the conflicting evidence of strain 44, further work on the effect of root grading would seem advisable.

From the percentage of male and female plants in Table 3 it is of interest that while the proportions of male and female plants were equal in the plots of graded and ungraded roots of strain 44, the proportions were unbalanced with respect to the corresponding plots of commercial strain. From X^2 tests of the number of staminate and pistillate plants in the plots of graded and ungraded roots of each strain it was evident that all except the plants of ungraded roots of the commercial strain were in agreement with the expected 1 : 1 ratio. Further X^2 tests on plants concerned in this unbalanced ratio indicate that those from greenhouse sown seed were in a 1 : 1 ratio while those from field sown seed were not. A possible explanation is that the male seedlings were weaker and, while able to survive under greenhouse conditions, more male seedlings may have failed to survive in the field. It has been suggested by Tiedjens (17) that staminate plants die out sooner than pistillate although Flory (3) found a 1 : 1 ratio to be expected in asparagus. Male plants outyield female plants as previously stated, and if male plants outyield female plants by as much as 25% as suggested by Tiedjens it is interesting to speculate as to the possible yields of the graded and ungraded roots of the commercial strain if the ratio of male and female plants had been more nearly the same for both strains. However, it is questionable if one could explain all of the differences in yield by the difference in the ratio of male and female plants. The possibility must not be overlooked that grading of the roots may have a differential effect with different strains, and that grading the roots of the commercial strain offered a better opportunity to eliminate weak plants than the grading of the selected strain 44.

Time of Seed Sowing as Related to Yield

The mean yield of the plants produced from seed sown outdoors in May was 1.03 tons per acre and the mean yield of the plants from seed sown in the greenhouse in February was 0.97 tons per acre. Since the F value for seeding time shown in Table 1 is significant at the 5% point it is apparent that the plants from seed sown outside in the usual manner significantly outyielded the plants from seed sown earlier in the greenhouse. Although the plants from both inside and outside sown seed were 2 years old, those which had been started inside were very large at the time of planting in the permanent location. The difference in yield in favour of the outside sown seed may have been due at least in part to the definite check in growth sustained by the large plants from the greenhouse sown seed.

SUMMARY

No appreciable improvement has been made in asparagus since the introduction of the variety Mary Washington 25 years ago. There is no general agreement as to the advisability of grading roots at planting time and discarding small crowns. In 1933 five strains, 14, 35, 38, 40, and 44, the progeny of five high-yielding female plants which had been isolated with two high-yielding male plants, were planted along with a commercial strain of the Mary Washington variety at the Horticultural Experiment Station, Vineland, Ontario. These strains were compared on the basis of yields of 6-to-8-inch spears recorded for 4 years. Some of the main results may be summarized as follows:

1. The five selected strains and the commercial strain could be divided into 2 yield groups with 3 of the selected strains in the high-yielding group and the other 2 selected strains and the commercial strain in the lower-yielding group.

2. The 2 highest-yielding strains were also the highest-yielding for the initial one-third of the harvest season and in general the 6 strains rank in the same order for early and total yield which might indicate a close relationship between early yield and total yield.

3. The results obtained from grading the roots of one selected strain and the commercial strain suggest that in general it is desirable to grade the roots before planting. However, in view of some conflicting evidence and the limited scope of the experiment further work would seem advisable.

4. Sowing seed in the greenhouse in February and transplanting the plants outdoors in May at the usual time of seed sowing produced plants which, when planted in the permanent location as 2-year-old plants, were very large and received a definite check in growth. The plants grown from seed sown in the greenhouse did not yield as much as the plants grown from seed sown outdoors at the usual time of seed sowing.

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GROWTH STIMULATION IN IRIS BULBS BY UREA[1]

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The practice of Oriental gardeners of soaking narcissus and other bulbs in aged urine before planting suggested that the immersion of iris bulbs in urea solutions might reduce the losses that glasshouse operators sustain through bulb rots caused by *Penicillium* sp. and other bulb pathogens; and the report by Bawden and Pirie (1), which showed that urea will inactivate certain plant virus suspensions, suggested that a prolonged immersion of bulbs in a urea solution might destroy virus infection.

EXPERIMENTAL

For three years in succession, small lots of iris bulbs were immersed in a 1% solution of urea and forced under glass in the usual manner. The urea treatments, as shown by the data in Table 1, induced longer stems and earlier and more abundant bloom than occurred in the controls. The foliage that developed upon the urea-treated bulbs was also deeper green in colour. The healthy appearance of the foliage, bulbs, and fibrous roots of the controls indicated that the stimulation was not due to the control of parasitic fungi or to the destruction of virus infection. However, virus disease in the iris varieties Wedgewood and Supreme is wide-spread and diagnosis is not easy.

TABLE 1.—THE INFLUENCE OF THE IMMERSION OF 9 CM. IRIS BULBS IN 1% UREA ON EARLINESS AND ABUNDANCE OF BLOOM

Season, Immersion date, Variety	No. of bulbs	Immersion period	First bloom	Stem length	Quantity of bloom
				in.	%
1932–33, Sept. 11, Wedgewood	30	Urea 3 hrs.	Jan. 24	18.5	90
	30	Water 3 hrs.	Jan. 28	17.0	70
	30	Untreated	Jan. 29	16.5	78
1933–34, Oct. 28, Wedgewood	24	Urea 24 hrs.	Jan. 13	19.0	96
	24	Water 24 hrs.	Jan. 17	14.0	75
	24	Untreated	Jan. 18	15.0	66
1934–35, Oct. 12, Supreme	19	Urea 24 hrs.	Jan. 9	—	100
	19	Water 24 hrs.	Jan. 13	—	66
	19	Untreated	Jan. 13	—	55

Virus disease symptoms tend to disappear under favourable growing conditions, hence a quantity of bulbs was selected from plants that bore definite virus symptoms and these were immersed for twenty-four hours in a 1% urea solution. As illustrated by the data in Table 3, no evidence was obtained that the treatment destroyed the virus involved in iris mosaic.

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The inspection of the small scale laboratory trials led to the adoption of a twenty-four hour immersion in a 1% urea solution as an annual routine practice by local glass-house operators, and Brown Bros., Esquimalt, B.C., reported that they secured 85% bloom with urea-treated Wedgewood iris compared with 55% bloom in the controls. Although the forcing experiment of Brown Bros. was inspected and earlier bloom and growth stimulation through the urea treatment was apparent, the data are not included in Table 2. During the 1945–46 season, the Wooldridge Bulb Co., Saanichton, B.C., carried out a large scale experiment upon the influence of urea. Since the experiment was closely supervised, the data therefrom are given in Table 2.

TABLE 2.—THE INFLUENCE OF THE IMMERSION OF WEDGEWOOD IRIS BULBS IN 1% UREA ON EARLINESS AND ABUNDANCE OF BLOOM. A COMMERCIAL TRIAL

Season, Immersion date, Size	No. of bulbs	Immersion period	First bloom	Quantity of bloom
				%
1945–46,				
Aug. 7, 10 cm.	2428	Urea 24 hrs.	Dec. 21	80
	3150	Untreated	Dec. 28	72
Aug. 7, 9 cm.	2552	Urea 24 hrs.	Dec. 23	60
	2944	Untreated	Jan. 1	55

TABLE 3.—THE INFLUENCE OF THE IMMERSION OF 8 CM. MOSAIC INFECTED WEDGEWOOD BULBS IN 1% UREA FOR 24 HRS. ON BLOOM DEVELOPMENT AND VIRUS SYMPTOMS

Season, Immersion date	No. of bulbs	Immersion period	Bloom cut				Virotic plants
			Dec. 30	Jan. 5	Jan. 10	Jan. 13	
1941–42							
Aug. 20	50	Urea 24 hrs.	11	9	8	0	27*
Sept. 12	50	Urea 24 hrs.	2	9	6	3	30
Sept. 12	50	Water 24 hrs.	1	7	8	5	31

* Plants bearing unquestionable virus disease symptoms.

DISCUSSION

In all forcing trials with the varieties Wedgewood and Supreme, earlier and more abundant bloom was induced by immersing the bulbs in a 1% urea solution up to twenty-four hours. In all trials the healthy appearance of the fibrous roots, bulbs, and foliage of the treated and control plants after the bloom had developed indicated that the stimulation by urea was not due to the destruction of fungus pathogens or to the destruction of virus disease. In the 1941–42 trials with small lots of bulbs known to be infected with iris mosaic, the symptoms of mosaic were more difficult to detect in the plants from urea-treated bulbs than in the controls, due to the induction of greater vigour by the urea, but the number of plants that bore definite mosaic symptoms were practically identical in the treated compared with the controls.

The practice of treating iris bulbs with urea has proved to be of considerable economic importance to local forcers, not only because the yield of bloom is increased, but also because the early bloom is often the most profitable. In the 1945–46 commercial scale trials, the urea-treated and the control bulbs were subsequently stored for three weeks at approximately 46° F., a treatment which in itself tends to induce earlier and more abundant bloom, but this cool storage treatment did not mask the influence of urea. No critical evidence was obtained upon the optimum period of immersion. Since both the three hour and the twenty-four hour period were beneficial, the local iris forcers have adopted an immersion period of from twelve to twenty-four hours, depending upon the weather. When the weather is warm a shorter period is adopted than when the weather is cool.

SUMMARY

Iris bulbs that had been immersed up to twenty-four hours in a 1% solution of urea produced longer flower stems, deeper green foliage, and earlier and more abundant bloom than untreated bulbs when the bulbs were forced in a normal fashion under glass. The urea immersion increased the vigour of mosaic infected bulbs and to a slight degree masked the disease symptoms, but the number of plants that bore definite mosaic symptoms were practically identical in the treated and in the controls. No evidence was found that the stimulation by urea was due to the destruction of fungus pathogens or to the destruction of virus disease.

THE GROWTH OF *SCLEROTINIA SCLEROTIORUM* AND *ALTERNARIA SOLANI* IN SIMPLE NUTRIENT SOLUTIONS[1]

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The study of the growth of *Sclerotinia sclerotiorum* (Lib.) de Bary and *Alternaria Solani* (E. & M.) Jones & Grout in simple nutrient solutions was undertaken to establish a standard nutrient solution that contained only essential basic constituents. A simple mineral-dextrose solution was adopted as the starting point. It consisted of a mixture of potassium phosphate, potassium nitrate, and dextrose, for no measurable growth was obtained when the sugar or any of the constituent ions of these compounds were omitted. Throughout this investigation the introduction of traces of nutrients, through the inoculum and through impurities in the C.P. chemicals used, has been ignored.

EXPERIMENTAL

In this study, 25 ml. portions of the nutrient solutions in 250 ml. Erlenmyer flasks were each inoculated with a small portion of mycelium taken from the periphery of Petri dish agar cultures, and the flasks were incubated for 10 days at 25° C. After the completion of the incubation period, each mycelial mat was transferred to a beaker containing 100 ml. of distilled water and re-transferred after one hour from the water to a weighing dish in which the mat was dried to constant weight at 100° C.

The nutrient solutions employed, designated in a manner to indicate their composition, are as follows:

K . P . NO_3	
K_2HPO_4	0.2 g.
KNO_3	0.2 g.
Dextrose	20.0 g.
Water	1000.0 ml.

K . P . Mg . S . NO_3	
K_2HPO_4	0.2 g.
KNO_3	0.2 g.
$MgSO_4$	0.1 g.
Dextrose	20.0 g.
Water	1000.0 ml.

K . P . Mg . S . Ca . NH_4	
K_2HPO_4	0.2 g.
$(NH_4)_2HPO_4$	0.2 g.
$MgSO_4$	0.1 g.
$CaSO_4 7H_2O$	0.1 g.
Dextrose	20.0 g.
Water	1000.0 ml.

K . P . Mg . NO_3	
K_2HPO_4	0.2 g.
KNO_3	0.2 g.
$MgHPO_4 . 7H_2O$	0.1 g.
Dextrose	20.0 g.
Water	1000.0 ml.

K . P . Mg . S . $CaNO_3$	
K_2HPO_4	0.2 g.
KNO_3	0.2 g.
$MgSO_4$	0.1 g.
$Ca SO_4 . 7H_2O$	0.1 g.
Dextrose	20.0 g.
Water	1000.0 ml.

K . P . Mg . S . Ca . Asparagin	
K_2HPO_4	0.2 g.
$MgSO_4$	0.1 g.
$CaSO_4$	0.1 g.
Asparagin	0.2 g.
Dextrose	20.0 g.
Water	1000.0 ml.

The results are given in Table 1.

DISCUSSION

When *Sclerotinia sclerotiorum* and *Alternaria Solani* were grown in liquid media containing K_2HPO_4, KNO_3, and dextrose, the dry weight of the mycelia progressively increased with the successive addition of the

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TABLE 1.—WEIGHTS OF *Sclerotinia sclerotiorum* AND *Alternaria Solani* mats after 10 days growth at 25° C.

Media	*Sclerotinia sclerotiorum*			*Alternaria Solani*		
	No. of cultures	Mean wt. and error	Final pH	No. of cultures	Mean wt. and error	Final pH
		mgs.			mgs.	
K . P . NO_3	5	43 ± 4.5	2.5 - 2.6	11	26 ± 0.8	6.9 - 7.1
K . P . Mg . NO_3	5	54 ± 4.0	2.5 - 2.6	6	35 ± 1.3	6.9 - 7.2
K . P . Mg . S . NO_3	7	96 ± 4.9	2.5 - 2.6	11	75 ± 1.0	7.0 - 7.2
K . P . Mg . S . Ca . NO_3	8	131 ± 7.7	2.5 - 2.7	11	83 ± 3.2	6.8 - 7.0
K . P . Mg . S . Ca . NH_4	8	103 ± 7.6	2.4 - 2.5	8	16 ± 1.0	3.7 - 4.3
K . P . Mg . S . Ca Asparagin	8	73 ± 5.7	2.7 - 2.8	9	70 ± 3.3	6.4 - 6.8

Necessary difference for 5% of significance = 8.4.

ions $Mg+$, SO^4-, and $Ca+$, with the possible exception of $Ca+$ in the *A. Solani* cultures where the difference was less than the 5% level of significance. The replacement of the NO_3- ion with NH_4+ had only a small inhibitory effect upon the growth of *S. sclerotiorum* but a very pronounced inhibitory effect upon the growth of *A. Solani.* The growth of *A. Solani* was less in the media containing all the mineral salts and the NH_4+ ion than in the mineral deficient media containing only K_2HPO_4 and KNO_3 in addition to dextrose. Unlike *S. sclerotiorum*, *A. Solani* either cannot utilize effectively the ammonium ion as a sole source of nitrogen or else the acid formed in the presence of the ammonium ion has a pronounced inhibitory effect. The final values of pH of all the *A. Solani* cultures were close to the neutral point, except in the cultures containing the ammonium salts, where the final values varied from pH 3.7 to pH 4.3. Neither fungi grew as well in the cultures containing asparagin as the sole source of nitrogen as in the corresponding complete nutrient cultures containing nitrate. Asparagin, however, proved to be a satisfactory source of nitrogen for both fungi.

SUMMARY

When *S. sclerotiorum* and *A. Solani* were grown in liquid media containing K_2HPO_4 and KNO_3 in addition to dextrose, the weights of the mycelia progressively increased with the successive additions of the ions $Mg+$, SO_4-, and $Ca+$. The replacement of NO_3- with NH_4+ had a marked inhibitory effect upon the growth of *A. Solani*, but inhibited only slightly the growth of *S. sclerotiorum*. Although inferior to nitrate, asparagin was a good source of nitrogen for both fungi.

THE LONGEVITY OF *PHOMA BETAE* IN GARDEN BEET SEED[1]

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The longevity of *Phoma Betae* Frank in garden beet seed, variety Detroit Dark Red, was studied as part of an exploratory program of ways and means of preventing the introduction through seed of plant disease into newly established seed growing areas in British Columbia. The possibility existed that the longevity of certain plant pathogens in seed was shorter than the period that the host seed could be stored without effecting a serious reduction in germination.

EXPERIMENTAL

In this study of the longevity of *Phoma Betae* in garden beet seed, the sample of seed was stored in a cool dry cellar. The sample was grown in the Northern Okanagan district, and the 1940 comparative trials of B.C. Certified seed showed that a high percentage of the seed therein was infected with *Phoma Betae.* Each year one or more samples of 100 clusters were withdrawn and planted equally spaced in flats of autoclaved soil. Table 1 is a record of the percentage of the clusters in which one or more seeds germinated, the total number of seedlings that developed from each sample of 100 clusters, and the percentage of the seedlings that were killed through *Phoma Betae* infection.

TABLE 1.—THE LONGEVITY OF *Phoma Betae* IN GARDEN BEET SEED SAMPLES OF 100 CLUSTERS

Time of year	Planting month	Cluster germination	Number of seedlings	Seedling* death
		%		%
1940	Dec.	80	121	33
1941	May	82	132	23
1942	Mar.	79	132	23
	Mar.	89	128	24
1943	May	82	127	20
	May	81	126	21
	June	81	124	22
	June	80	127	19
1944	Feb.	84	134	4
1945	Jan.	93	169	4
	Oct.	92	156	3
	Dec.	94	158	2

* Based primarily on the 1943 replications, differences less than plus or minus 2 have little significance.

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DISCUSSION

Although the decrease with the age of the seed of seedling deaths through *Phoma Betae* infection is of interest, seed-borne infection is seldom if ever of sufficient economic importance to justify the establishment of a five-year seed-storage period as a control measure. The five-year seed-storage period had no adverse effect upon germination. The data in Table 1 suggest that the slight increase in germination strength after storing for five years may be significant, but as so many factors influence seed germination, the inference is not drawn that the slight increase in the germination strength is due to the decrease in the amount of *Phoma Betae* infection. The increase in germination would probably have escaped notice had not Mr. C. Tapp, Seed Analyst, Vancouver, B.C., discovered a similar case. Upon re-testing a five-year-old sample of well matured garden beet seed, he found the germination had improved.

Although the introduction of *Phoma Betae* into new seed-growing districts apparently cannot be prevented by using five-year-old seed, nevertheless, plant pathologists should not neglect the possibilities of preventing the introduction of disease by the simple expedient of using old seed. This may be illustrated by seed transmission studies of tomato streak, *Lycopersicum* virus 1. A 72% transmission was obtained when the seed and adhering pulp were planted immediately after the diseased fruits were harvested. After the seed was thoroughly freed from the pulp by shaking in a 2% sulphuric acid solution, the transmission value fell to 30%. When the acid cleaned seed was stored for one year, the transmission values varied from zero to 4%.

SUMMARY

Seedling death in garden beets, variety Detroit Dark Red, through *Phoma Betae*, decreased with the age of the seed from over 30% to less than 5% over a five-year seed-storage period, and over the same period there was no decline, but rather a slight increase in the germination.

GERMINATION OF WEED SEEDS

I. LONGEVITY, PERIODICITY OF GERMINATION, AND VITALITY OF SEEDS IN CULTIVATED SOIL[1]

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The earth's surface is clothed with a cover of vegetation, except under conditions of continually frozen ground or extremely arid climate, or where man deliberately attempts to keep the land free from all forms of growth. Numerous natural and artificial agencies tend to suppress or destroy this vegetative cover, but plants continue to spring up from bare ground. During years of extreme drought and wind erosion, millions of acres of land in the arid and semi-arid regions of North America have been laid bare for many months at a time. Yet with one good rain and a relatively short period of fairly stable atmospheric conditions, plant growth reappeared over many of the stricken areas in sufficient amounts to give complete protection against subsequent damaging effects of high wind and heavy downpours of rain.

The ability of many plant species to reappear in areas denuded of vegetation is due principally to dormancy of seeds. Dormancy, or resting period, of seeds buried in the soil is particularly long in a great number of plant species, especially those depending on natural conditions for propagation. Hence, once land has become clothed with a natural cover of vegetation, it is virtually impossible for any agency to destroy it permanently, for many seeds that may shatter on the ground will remain in a dormant state for many years and the small proportion of them that germinate in any year may reach maturity and add more seeds to those already present in the soil. This characteristic behaviour, particularly of species not propagated by man, such as weeds, constitutes one of the major natural factors in soil conservation. Yet this very characteristic, essential as it may be for soil conservation, often brings serious difficulties for man on the land. Many weeds are serious pests by virtue of the fact that dormant seeds shatter in large numbers and keep springing up in cultivated crops. Competition for moisture and plant food is generally acute in highly infested fields and losses sustained in lowered quality and reduced yields of crops are often very great.

It should be pointed out that seeds of some weeds do not exhibit a marked dormancy and for this reason alone may be controlled or eradicated by methods that are different to those suitable for weeds whose seeds exhibit a high degree of dormancy in the soil. When plowed under, seeds of a low degree of dormancy will germinate, and if buried too deeply will rot away without emerging. Those exhibiting a high state of dormancy, on the other hand, will be preserved by burial and will germinate only after they are brought nearer to the surface.

[1] Contribution from the Experimental Farms Service (P.F.R.A.), Dominion Department of Agriculture, Ottawa, Canada.
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A successful control of weeds necessitates the destruction of viable seeds. It is essential therefore to create such condition of the soil that would tend to stimulate germination of dormant seeds, which later may be destroyed by tillage. There is far too little information at the present time on the relative dormancy of seeds of different weeds and on the conditions that favour their germination. Such information is of great importance in relation to tillage practices. A knowledge of the causes of dormancy of weed seeds, their behaviour under various conditions in the soil, and the methods by which they could be most readily destroyed, will aid the scientist and the farmer in working out effective methods of eradication.

In order to answer some of the elementary questions connected with the nature and degree of dormancy of seeds of different weeds and the methods of cultivation that would facilitate their eradication, a series of experiments was undertaken at this laboratory in 1937, the results of one of which are reported herewith.

LITERATURE

There are many records of longevity of weed seeds in undisturbed soil. The two most extensive buried seed projects on which considerable data are available are those initiated by Beal (7) in 1879 and by Duvel (10) in 1902. These and other experiments (5) show that seeds of many weeds retain their vitality in undisturbed soil for 60 years or more. Hard seeds that do not absorb water were found to be especially adapted for long periods of vitality in moist soil. However, many of the weed seeds of long life span in soil are not hard and imbibe water freely, yet stored food in these seeds is not soon exhausted by respiration. Atwood (1) found that the initial rate of respiration of dormant imbibed seeds of *Avena fatua* is high at first but that the rate soon drops to a very low level, suggesting that curtailment of respiration must be enormous for seeds buried in moist soil. Crocker (5) concludes from comparative results of Ewart (8) and Beal (7) that the life span of some seeds buried in the soil is longer than in ordinary dry storage.

Although there are numerous records of the length of life of seeds in undisturbed soil, such as in sod, little information is available on length of life in cultivated soil. Of the very few such experiments, those of Brenchley and Warington (2, 3, 4) are outstanding. In these investigations a thorough analysis was made of the effect of different cultural and cropping methods on the weed seed population of the soil and on the nature and length of period of dormancy of seeds of many weeds. Brenchley and Warington (2) assert that dormancy is of two distinct types, "natural" and "induced". Natural dormancy is due to some physiological state of the seed that prevents germination, even in a favourable environment. Induced dormancy, on the other hand, is forced upon the seeds by some condition of the environment that is unfavourable for germination, such as the exclusion of oxygen supply resulting from deep burial in the soil. At low depths in the soil some seeds are able, by force of conditions, to retain their viability for many years.

The naturally dormant seeds will germinate as soon as they reach a physiological state that enables them to germinate, provided that environ-

mental conditions are suitable. A statement that seeds of certain species are able to stay dormant in the soil for some definite period, however, does not mean that all seeds in any given sample would behave in this manner. A certain proportion may exhibit no period of natural dormancy and will germinate as soon as they are subjected to favourable conditions. Others will follow in order, however, until all have germinated. The length of period required for all the seeds to reach a state that allows them to germinate has been designated as their natural period of dormancy (2).

For many weeds, the period of natural dormancy is believed to be much shorter than the period of induced dormancy. Hence seeds that are reputed to remain viable in undisturbed soil for 60 years or more, may, under suitable cropping and tillage practices, grow out of the soil in the course of a few years. This puts the weed control problem in new light, for weeds that were once believed impossible of eradication within the course of several decades might be destroyed with appropriate methods within much shorter periods. The general trend in agricultural practice in Western Canada is to work the land as shallow as is consistent with effective destruction of weed growth. Weed seeds under such procedure are not buried deeply and the majority are in a position to germinate as soon as they are physiologically ready for germination. Their longevity in shallow cultivated soil is therefore more comparable to the period of natural dormancy than to period of induced dormancy caused by the older and now more or less obsolete tillage practices.

Since little information is available on the periods of seed dormancy for different weeds in shallow cultivated soil, and since the knowledge of the behaviour of weed seeds in the soil is believed to be essential in working out effective methods of weed control, it was decided to undertake the study on this phase of the problem.

MATERIALS AND METHODS

Weed seeds chosen for investigation were taken at random from samples grown during the current year. Three sets of seeds, originating in 1937, 1938, and 1940, were chosen for the experiment. The seeds were mixed into a 2.5-inch layer of moist sterilized clay, loam, and sandy loam soil and were put into open bottom galvanized iron frames 12 inches square in the field about November 15.

The soil immediately below the layer containing the weed seeds was sterilized to the full depth of 6 inches. No seedlings appeared immediately after November 15 but records of seedlings emerging during the next and each succeeding year were made as soon as they appeared. The seedlings were identified, counted, and pulled out with the roots soon after emergence, but where doubt existed as to their identity they were left to grow until such time as they could be definitely identified. Care was taken that no soil sticking to the roots was thrown out and that no roots that might produce new shoots were left in the ground.

To avoid contamination, the area in the immediate vicinity of the trays was covered with a 3-inch layer of coarse gravel and this area was fenced in with fine chicken netting. A similar fence was placed some distance away and the ground between the fences and on the outside was sown per-

manently to grass. The trays were covered with tar paper from about November 15 to March 31 in order to avoid weed seeds being blown in with the snow. The ground was frozen and virtually no germination occurred during this period. Only one seedling out of a total of many thousands emerged early in November, hence all records of emergence cover periods only from April 1 to October 31.

In order to ascertain as to whether or not any weed seeds found their way in from the outside, 9 trays out of a total of 288 were filled with sterilized soil and seedlings that appeared in these trays were concluded to have been brought in from the outside. Seedlings of 4 species *Salsola Pestifer*, *Portulaca oleracea*, *Amaranthus retroflexus*, and *Monolepis Nuttalliana* grew in the blank trays but in such low numbers that they could not possibly interfere with the general results for these particular weeds.

The soils in the trays were kept in fallow one year and sown to spring wheat or barley in alternate years. The treatment of fallow consisted of turning the soil over with a trowel 2 or 3 times during the season and to the depth not exceeding 3 inches. This had to be done very carefully to avoid destroying the seedlings which might be in the soil but not emerged. The soils were worked once to a similar depth during the crop year, this being done just prior to seeding.

The tillage and cropping treatment described above was continued for 3 years with the 1937 seeds, for 6 years with the 1938 group, and is still being continued with the 1940 seeds. After field treatment, the soils of the first two groups were washed through an 80-mesh sieve, which was fine enough to prevent the loss of even the smallest seeds. The residue, along with the seeds that survived the field treatment, was placed in shallow saucers in a layer not exceeding 1 inch in depth and subjected to repeated germination tests in the laboratory with occasional stirring until no more seeds would germinate. It was concluded, if seedlings failed to appear for a period of 2 consecutive years, that all viable seeds had germinated. The length of time required for all seeds to germinate varied from a few weeks to many years, depending on the species. Except for hard seeds, however, most of the seeds germinated within 3 years.

Each species favoured a particular temperature and moisture condition for germination. *Salsola Pestifer* germinated in large numbers under a temperature of about 40° F. and under a relatively low soil moisture content. *Portulaca* and most members of the *Amaranthaceae* family, on the other hand, required periods of high temperature and relatively low soil moisture content before they would germinate. The samples under experiment were subjected to germination under variable temperature and moisture conditions in order to effect the possible maximum germination of all weeds in the shortest possible time. The samples were frozen on several occasions.

RESULTS

The numbers of seedlings emerging in each tray in the field have been grouped in semi-monthly periods in order that some estimate may be made of the exact length of dormancy of the seeds of each species and of the effect of season on germination.

It is seen that some seeds germinated immediately after they were placed under suitable conditions in the field, indicating that they were physiologically ready for germination and all that was required was to place them in a favourable environment. A certain proportion of the remaining seeds, however, kept on emerging out of dormancy and germinating until all had grown out of the soil. The period required for all seeds to germinate is designated as the maximum period of dormancy. The rate of emergence from dormancy, and hence the frequency of germination, varied greatly, depending upon the characteristic habit of the species. In some, the maximum period of dormancy was only a matter of a few months, in others many years.

In addition to the differences in the maximum period of dormancy there were also differences in the relative frequency of emergence from dormancy within the life span of all the seeds. Species differed greatly in this respect, some showing relatively few seeds emerging out of dormancy and germinating during the first year, followed by a fair proportion germinating each year thereafter until all had germinated. Other species, even with the same maximum life span of seeds, showed a relatively high emergence during the first year followed by relatively few emerging throughout subsequent years.

This variation in germination has a very important bearing on the practical aspect of weed control. It is evident that longevity, or length of dormancy, for the two cases cited above would be either the same or widely different, depending on the viewpoint that is to be adopted. If longevity is to mean the length of period required for all the seeds to grow out of or lose their viability in the soil, then it would be identical in the two cases cited. If, on the other hand, longevity, or length of dormancy, is to mean the *average* life span of all the seeds of a given sample, then it would be much greater in the former than the latter case.

From the point of view of weed eradication, consideration of the maximum period of dormancy would seem to be of paramount importance, but from the standpoint of weed control information on the average period of dormancy would be at least equally important. From what follows, it will be shown that many species produce a relatively large proportion of seeds that lie dormant, even under the most favourable environment for germination, for periods longer than the duration of any practical farm program that might be undertaken to rid the soil of weed seeds. There is, therefore, little hope of ever being able to rid the land of some weeds and the general farm practice that is to be adopted must be of such a nature as to enable the farmer to attain the maximum possible control of these weeds.

The average period of dormancy of seeds of different weeds was deterined by summing the products of the number of months between the seeding of weed seeds and their germination and the percentage of germinaation within each particular month. For seeds of exceedingly long period of dormancy, however, the average period of dormancy could not be determined from the results so far obtained and these species were therefore classified on the basis of their relative length of seed dormancy. The relative length of seed dormancy was determined by summing the products

TABLE 1.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL

(Maximum tillage depth 3″; no seeds were put below this depth; an indefinite number of seeds was sown on Sept. 18, 1937, but subsequent pollution of the soil was prevented)

Weed	Clay				Loam				Sandy loam			
	Emerged in the field			Viable seeds left*	Emerged in the field			Viable seeds left*	Emerged in the field			Viable seeds left*
	1938 (fallow)	1939 (wheat)	1940 (fallow)		1938 (fallow)	1939 (wheat)	1940 (fallow)		1938 (fallow)	1939 (wheat)	1940 (fallow)	
	%	%	%	%	%	%	%	%	%	%	%	%
Bromus tectorum	100.0	0	0	0	100.0	0	0	0	100.0	0	0	0
Agropyron repens	82.8	3.4	10.3	3.5	76.3	0	2.6	21.1	73.6	2.9	8.8	14.7
Setaria viridis	99.2	0.8	0	0	100.0	0	0	0	100.0	0	0	0
Bilderdykia Convolvulus	98.5	1.5	0	0	98.9	0	1.1	0	96.8	3.2	0	0
Chenopodium album	47.4	1.5	8.8	42.3	44.6	9.5	27.2	18.7	44.9	2.1	32.9	20.1
Axyris amaranthoides	65.0	7.0	15.9	12.1	69.8	24.0	3.1	3.1	36.0	13.8	16.9	33.3
Salsola pestifer	98.4	1.3	0	0.3	100.0	0	0	0	99.5	0.5	0	0
Amaranthus retroflexus	53.8	2.0	4.2	40.0	30.3	0.4	13.7	55.6	71.1	0.4	12.1	16.4
Amaranthus blitoides	79.5	1.0	0	19.5	89.3	0.5	1.3	8.9	87.3	3.0	0.8	8.9
Amaranthus graecizans	20.4	1.2	4.2	74.2	19.6	2.8	11.9	66.4	27.5	0	0.2	72.3
Portulaca oleracea	19.8	1.4	8.9	69.9	18.1	2.3	32.3	47.3	48.9	3.8	19.1	28.2
Baccaria vulgaris	100.0	0	0	0	99.4	0.6	0	0	100.0	0	0	0
Lepidium perfoliatum	7.0	0.5	6.4	86.1	22.6	0.5	5.3	71.6	19.5	0	18.9	61.6
Lepidium densiflorum	4.3	0.7	4.6	90.4	34.2	1.5	10.5	53.8	8.2	0.4	13.5	77.9
Thlaspi arvense	77.0	10.7	3.6	8.7	94.3	4.4	0.5	0.8	98.1	1.4	0	0.5
Sisymbrium altissimum	63.0	0.2	18.4	18.4	65.2	0.6	17.9	16.3	37.9	0	23.2	38.9
Sophia multifida	29.0	3.2	19.4	48.4	74.4	0	12.8	12.8	44.0	0	8.5	47.5
Conringia orientalis	100.0	0	0	0	100.0	0	0	0	98.0	2.0	0	0
Sinapis arvensis	93.6	1.5	3.4	1.5	97.7	1.7	0.6	0	99.0	0	0.5	0.5
Brassica juncea	99.4	0.6	0	0	100.0	0	0	0	100.0	0	0	0
Convolvulus americanus	5.0	1.0	7.1	86.9†	3.2	0.0	4.3	92.5†	5.5	3.3	4.4	86.8†
Lappula echinata	69.7	0	30.3	0	84.6	0	7.7	7.7	84.5	4.4	2.2	8.9
Solanum triflorum	93.5	5.9	0.6	0	90.1	9.5	0.4	0	98.2	1.6	0.2	0
Plantago major	9.6	1.2	2.4	86.8	11.7	3.4	17.2	67.7	11.2	3.0	6.4	79.4
Helianthus aridus	91.2	2.6	1.4	4.8	90.1	6.6	0.7	2.6	93.2	3.9	0.8	2.1
Lactuca virosa	44.6	8.9	16.6	29.9	38.8	6.1	31.6	23.5	50.5	1.9	28.6	19.0
Sonchus arvensis	43.3	16.2	2.7	37.8	66.7	13.3	0	20.0	86.7	0	3.3	10.0

* The number of viable seeds remaining in the soil at the end of 3 years of exposure in the field was determined by repeated germination tests in shallow trays in the laboratory until no more germinate.

† Hard seeds germinated after immersion in concentrated sulphuric acid for 24 hrs. Other species did not contain hard seeds.

TABLE 2.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL

(Tillage 3″ deep, no seeds being placed below this depth; seeds were sown on October 14, 1938)

Weed	No. of seeds sown in the field	Numbers germinated. *†	Clay: Numbers emerged in the field						Clay	Loam: Numbers emerged in the field						Loam	Sandy loam: Numbers emerged in the field						Sandy loam
			1939 fallow	1940 fallow	1941 crop	1942 fallow	1943 crop	1944 fallow	* Viable seeds left	1939 fallow	1940 fallow	1941 crop	1942 fallow	1943 crop	1944 fallow	* Viable seeds left	1939 fallow	1940 fallow	1941 crop	1942 fallow	1943 crop	1944 fallow	* Viable seeds left
Bromus tectorum	100	—	18	13	0	0	0	0	0	46	12	1	0	0	0	0	24	9	0	0	0	0	0
Agropyron repens	50	—	28	2	1	0	0	0	0	5	3	0	0	0	0	0	23	0	2	0	1	0	0
Avena fatua	100	—	50	19	3	0	0	0	0	39	13	1	0	0	0	0	28	11	0	1	0	0	0
Setaria viridis	300	35	13	0	0	0	0	0	0	11	1	0	0	0	0	0	18	0	0	0	0	0	0
Bilderdykia Convolvulus	100	64	69	0	0	0	0	0	0	47	3	3	0	0	0	0	67	4	0	0	0	0	0
Corispermum marginale	300	—	29	1	6	2	1	0	0	17	12	33	55	5	7	17	41	9	26	6	0	1	1
Chenopodium album	300	126	57	16	22	17	2	6	58	44	14	5	12	0	6	42	44	13	14	36	1	2	22
Asygris amaranthoides	300	135	100	8	6	5	1	1	21	58	18	8	1	0	0	70	85	6	11	8	1	1	43
Salsola pestifer	100	—	68	0	0	0	0	0	0	30	0	0	0	0	0	0	82	0	0	0	0	0	0
Amaranthus retroflexus	300	249	39	19	24	32	0	9	97	43	6	34	21	2	6	50	65	12	28	36	1	15	63
Amaranthus blithoides	300	207	78	0	15	44	2	9	80	40	0	47	52	0	11	54	45	7	46	89	0	21	42
Amaranthus graecizans	300	159	35	1	12	27	0	1	89	76	0	5	28	0	8	59	47	0	20	43	1	14	40
Portulaca oleracea	300	189	2	0	19	0	0	1	99	2	13	15	0	0	4	45	5	4	5	0	0	2	78
Vaccaria vulgaris	100	100	50	0	0	0	0	0	0	24	0	0	0	0	0	0	44	0	0	0	0	0	0
Lepidium perfoliatum	300	168	6	1	11	8	1	2	81	15	5	3	3	8	7	62	35	2	17	8	1	11	49
Lepidium densiflorum	300	—	7	7	4	8	0	8	49	13	3	11	5	2	9	25	36	5	17	7	0	7	30
Thlaspi arvense	300	177	93	44	41	78	1	3	0	58	19	11	6	0	0	0	137	17	18	7	0	0	0
Sisymbrium altissimum	300	201	53	0	4	5	1	1	6	22	16	15	26	6	14	6	71	1	26	12	0	20	9
Sophia multifada	300	165	6	4	7	4	0	0	65	9	14	6	10	4	4	26	15	20	18	7	1	4	29
Conbringia orientalis	300	210	158	1	0	0	0	0	0	32	1	0	0	0	0	0	105	0	0	0	0	0	0
Sinapis arvensis	300	189	123	11	11	19	0	6	8	54	8	15	14	0	3	5	117	19	7	2	0	0	0
Brassica juncea	300	300	97	0	0	0	0	0	0	10	0	0	0	0	0	0	104	0	0	0	0	0	0
Convolvulus americanus	50	—	2	1	1	1	1	2	10	0	5	1	0	0	0	8	1	4	0	2	0	0	8
Lappula echinata	300	264	111	3	0	0	0	0	0	25	0	2	0	0	3	0	130	2	0	0	1	0	0
Salanum triflorum	100	—	55	18	10	1	2	0	1	42	1	3	0	0	0	0	67	6	2	0	0	0	0
Cyclachaena xanthifolia	300	—	27	9	9	11	13	13	0	9	5	25	14	2	3	0	23	48	5	3	0	5	2
Helianthus aridus	100	44	60	0	0	3	0	0	0	20	1	0	0	0	0	0	40	1	1	0	0	0	1
Tragopogon dubius	30	—	23	0	0	0	0	0	0	2	0	0	0	0	0	0	8	0	0	0	0	0	0
Lactuca virosa	100	—	11	4	0	0	0	0	1	3	1	0	0	0	0	3	1	2	0	1	0	0	0
Sonchus arvensis	50	—	33	0	4	0	0	0	0	1	0	0	0	0	0	0	2	3	0	0	0	0	1

† Determined on another sample of the same seed from numbers germinating in 1 cm. layer of moist sand in the laboratory.
* As determined by repeated germination tests in shallow trays in the laboratory up to Jan. 21, 1946. Additional seeds of some species are expected to emerge after this date.

TABLE 3.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL

(Tillage 3" deep, no seeds being placed below this depth; seeds were sown between November 1 and 5, 1940.)

Weed	No. of seeds sown in the field	No. of viable seeds*	Clay					Loam					Sandy loam				
			Numbers emerged in the field					Numbers emerged in the field					Numbers emerged in the field				
			1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow
Bromus tectorum	1000	900	297	4	0	0	0	125	0	1	0	0	109	0	0	0	0
Agropyron repens	1000	390	322	0	1	0	0	456	0	0	0	0	396	1	0	0	0
Lolium rigidum	1000	620	484	28	0	0	0	393	14	1	0	0	347	10	0	0	0
Hordeum jubatum	1000	510	373	3	12	0	0	443	2	11	0	0	604	4	10	0	0
Avena fatua	1000	400	298	75	18	1	0	178	21	3	0	0	200	42	12	0	0
Setaria viridis	1000	760	562	3	8	0	1	531	0	0	0	0	468	0	0	0	0
Rumex mexicanus	1000	120	49	0	1	0	0	40	0	0	0	0	12	0	0	0	0
Polygonum neglectum	1000	310	275	44	10	4	0	168	7	1	2	2	166	15	0	2	0
Bilderdykia Convolvulus	1000	500	586	20	1	0	0	338	7	0	0	1	310	3	0	0	0
Chenopodium album	1000	550	24	4	43	27	4	18	7	10	16	6	6	7	6	20	11
Monolepis Nuttaliana	1000	760	33	1	10	13	12	42	1	5	5	16	36	1	10	31	19
Kochia trichophylla	1000	720	193	0	0	0	0	116	0	0	0	0	59	0	0	0	0
Corispermum marginale	1000	430	77	22	14	3	0	149	22	100	19	6	131	4	18	4	0
Atriplex hortensis	1000	870	567	5	9	0	0	487	22	25	5	2	230	6	4	0	2
Atriplex hastata	1000	490	331	2	26	19	0	319	12	2	5	2	344	46	11	17	2
Axyris amaranthoides	1000	590	221	39	31	32	10	118	37	15	28	2	80	36	21	14	3
Salsola Pestifer	1000	500	436	0	2	0	0	189	0	0	0	0	178	0	0	0	0
Amaranthus retroflexus	1000	710	276	1	11	27	4	147	1	8	9	6	148	0	9	20	5
Amaranthus blithoides	1000	370	265	4	22	47	20	222	28	11	32	14	212	41	22	33	10
Amaranthus graecizans	1000	340	174	1	0	39	7	121	4	15	31	5	135	0	21	14	1
Portulaca oleracea	1000	440	18	1	3	8	0	41	0	6	14	10	48	4	0	4	1
Spergula arvensis	1000	1000	72	0	27	10	2	68	16	13	10	2	99	13	28	18	3
Agrostemma githago	500	475	366	0	0	0	0	118	0	0	0	0	108	0	0	0	0
Silene noctiflora	1000	1000	265	5	141	23	3	201	4	53	30	3	216	12	122	20	16
Silene vulgaris	1000	950	197	8	34	28	9	197	2	11	9	6	132	2	9	8	0
Vaccaria vulgaris	1000	920	564	14	1	0	0	550	0	0	0	0	313	1	0	0	0
Lepidium perfoliatum	1000	670	55	1	18	7	25	81	0	24	10	14	44	0	8	6	3
Lepidium densiflorum	1000	1000	84	47	8	25	2	84	8	22	21	0	88	7	13	21	0
Thlaspi arvense	1000	970	266	115	45	11	1	187	35	23	1	0	300	47	99	3	0

TABLE 3.—LONGEVITY OF WEED SEEDS IN CULTIVATED SOIL—*Concluded*

(Tillage 3" deep, no seeds being placed below this depth; seeds were sown between November 1 and 5, 1940.)—*Concluded*

Weed	No. of seeds sown in the field	No. of viable seeds*	Clay: Numbers emerged in the field					Loam: Numbers emerged in the field					Sandy loam: Numbers emerged in the field				
			1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow	1941 fallow	1942 crop	1943 fallow	1944 crop	1945 fallow
Capsella Bursa-pastoris	1000	200	4	0	8	0	0	29	13	13	17	1	27	10	23	13	0
Camelina sativa	1000	960	450	0	0	0	0	424	0	0	0	0	318	0	0	0	0
Camelina dentata	1000	1000	487	0	0	0	0	708	0	0	0	0	631	0	0	0	0
Camelina microcarpa	1000	880	156	0	0	0	0	584	0	0	0	0	629	0	0	0	0
Sisymbrium altissimum	1000	970	78	0	6	1	0	81	0	7	3	1	13	1	2	0	0
Sophia multifada	1000	600	6	19	23	11	3	77	7	13	17	7	63	11	31	11	9
Conringia orientalis	1000	610	535	3	0	0	0	249	0	0	0	0	204	0	0	0	0
Cheirinia cheiranthoides	1000	350	61	7	19	21	3	48	3	15	18	5	53	2	28	12	1
Sinapis arvensis	1000	700	339	15	55	18	5	187	13	26	2	2	187	8	51	7	3
Erucastrum gallicum	1000	310	131	3	22	2	2	112	0	7	0	1	144	0	0	0	0
Brassica juncea	1000	990	345	0	7	2	0	154	0	0	0	0	52	0	0	0	0
Peritoma serrulatum	700	586	396	76	0	9	1	241	107	3	13	2	257	30	0	3	0
Medicago lupulina	1000	460	15	154	29	43	7	22	116	12	32	4	6	131	12	25	4
Oenothera strigosa	1000	430	13	8	2	26	0	74	8	11	19	3	102	19	4	30	0
Asclepias speciosa	1000	230	104	6	0	0	0	86	2	0	0	0	43	2	0	0	0
Convolvulus americanus	1000	570	24	1	2	3	7	8	1	3	4	13	8	1	1	5	10
Lappula echinata	1000	820	214	1	2	4	0	107	1	1	0	0	85	1	0	0	1
Plantago major	1000	380	106	0	0	0	3	22	2	0	16	1	17	0	0	22	8
Cyclachaena xanthifolia	1000	280	51	20	1	13	0	1	0	0	0	0	19	5	4	5	0
Xanthium echinatum	1000	280	163	48	1	8	3	162	56	4	5	1	100	70	0	0	0
Grindelia perennis	1000	530	14	23	12	13	0	29	33	18	27	2	6	21	1	6	2
Helianthus aridus	1000	340	363	75	19	26	3	36	21	2	0	0	82	14	0	1	0
Cirsium arvense	1000	40	27	1	0	0	0	21	0	0	0	0	8	2	0	0	0
Tragopogon dubius	250	230	71	0	0	0	0	53	0	0	0	0	20	0	0	0	0
Taraxacum officinale	1000	230	5	3	2	6	0	48	8	3	2	0	45	3	1	3	0
Lactuca Scariola	1000	150	112	3	7	7	0	27	5	1	1	1	35	2	0	2	1
Lactuca virosa	1000	160	126	4	0	0	0	22	4	0	0	0	22	12	0	0	0
Sonchus arvensis	1000	240	18	0	2	5	0	16	0	0	0	0	12	0	0	1	0

*Determined on another sample of the same seed from percentage of seeds germinating in 1 cm. layer of moist sand in the laboratory. The tests were continued from Nov. 6, 1940, to Nov. 15, 1945, towards the end of which period no more seeds except those of *Silene noctiflora*, *Medicago lupulina*, *Convolvulus americanus* and *Plantago major* would germinate. Seeds of these four were treated with concentrated sulphuric acid, after which treatment the viable seeds germinated immediately.

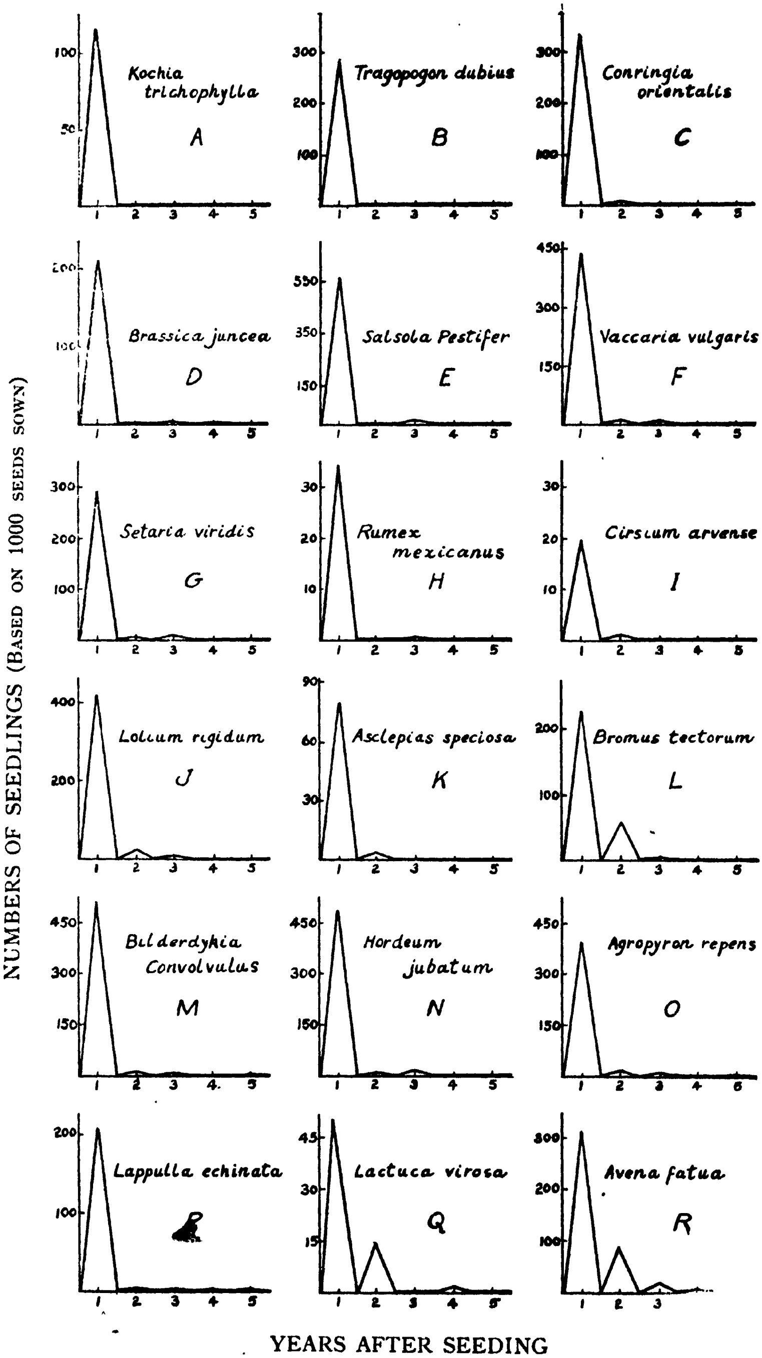

FIGURE 1. Yearly totals of seedlings emerging from cultivated soil during 5 years after seeding.

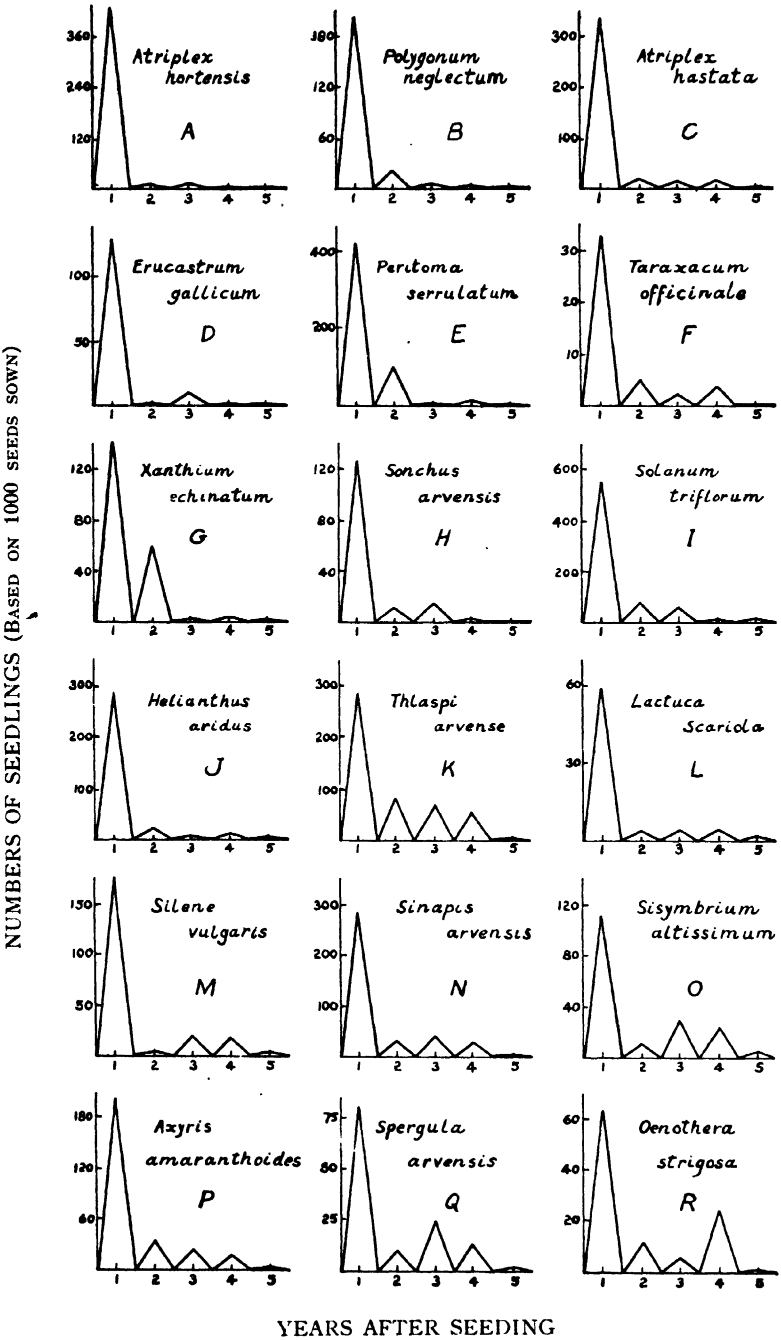

FIGURE 2. Yearly totals of seedlings emerging from cultivated soil during 5 years after seeding.

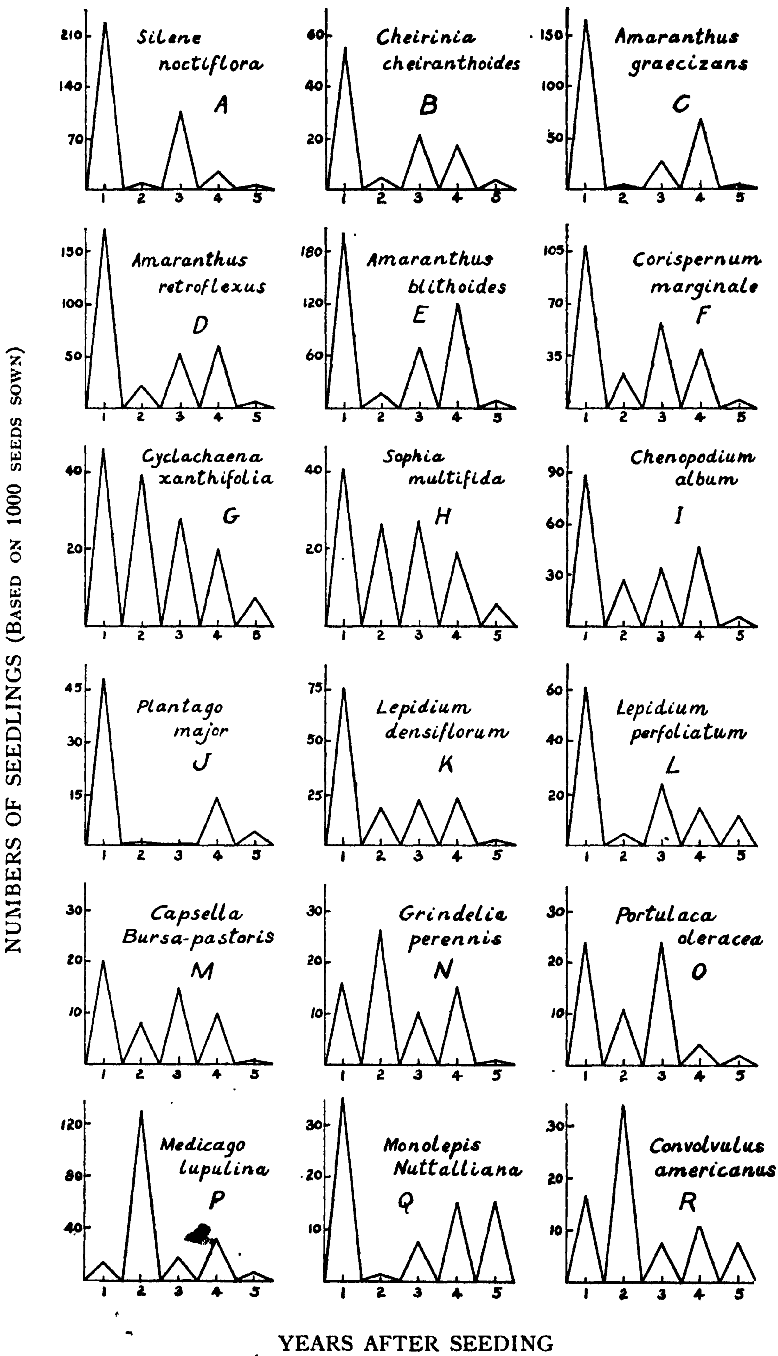

FIGURE 3. Yearly totals of seedlings emerging from cultivated soil during 5 years after seeding.

of the number of months between seeding and emergence and percentage of monthly germination. The monthly percentage was based on the total numbers germinating during a 5-year period. The average and the relative length of dormancy are determined in essentially the same manner and are therefore comparable.

The results of the experiment with the 1937 seeds are presented in Table 1. These results may be considered complete for all practical purposes. The data indicate the percentage of seeds, for each species, germinating during a 3-year period in the field and, as determined by laboratory tests already described, the percentage of seeds surviving the treatment in the field. As the number of species included in Table 1 was limited to 27, Tables 2 and 3, based on results for a more extensive number of species, are also presented. The data in Tables 2 and 3 are not fully completed, however, and samples are being kept under observation in order to follow the course of events still further. Because these latter experiments have not yet been completed, it is impossible at the present time to deal with the germination figures on a percentage basis, as in Table 1, and the results obtained to date are recorded merely by numbers of seeds germinating during each of the years the experiment has been conducted.

The data indicate the trend of results with respect to dormancy, but Figures 1, 2 and 3, based on the average results from Tables 2 and 3, have been prepared to show the trends more clearly.

It is evident that dormancy of weed seeds varies, depending on the year of origination. Hence the results given in this paper are exact only insofar as the behaviour of the particular samples of seeds chosen for experiment are concerned. Further experiments might change the average results, but judging from the results obtained on species common to each of the 3 sets of experiments, the variations are not particularly great in the majority of cases. Nevertheless, these experiments do indicate that the period of dormancy, as determined for seed of a given species maturing in any one year, cannot be assumed to be common to that particular species, and that in some cases these individual results might be at wide variance with the average.

On the whole, there were little, if any, differences in the average length of dormancy of seeds incorporated into clay, loam, or sandy loam soil.

The data indicate that while seeds of some species lie dormant in cultivated soil for only a very short time, many species contain a certain proportion of seeds that remain dormant in the soil for many years. The proportion of such seeds varies widely between different species and, in fact, no two species were found to be identical in this respect. Therefore, it was impossible to group them into distinct categories with respect to dormancy, but it was possible to list them according to the scale of shortest to longest average length of dormancy determined by the method already described. The maximum length of dormancy is also indicated in a general way.

LENGTH OF DORMANCY OF WEED SEEDS IN CULTIVATED SOIL:

(Listed in approximate order from shortest to longest average length of dormancy)

None to very short (maximum length of dormancy not exceeding 1 year):

1.	*Agrostemma githago*	Purple cockle, corn cockle
2.	*Camelina microcarpa*	Small seeded false flax
3.	*Camelina sativa*	False flax
4.	*Camelina dentata*	Round seeded or flat seeded false flax
5.	*Kochia trichophylla*	Kochia
6.	*Tragopogon dubius*	Yellow-goat's beard

Short to intermediate (maximum length of dormancy from 1 to 3 years):

7.	*Conringia orientalis*	Hare's ear mustard
8.	*Brassica juncea*	Indian mustard
9.	*Salsola Pestifer*	Russian thistle
10.	*Vaccaria vulgaris*	Cow cockle
11.	*Setaria viridis*	Green foxtail
12.	*Rumex mexicanus*	Willow-leaved dock
13.	*Cirsium arvense*	Canada thistle
14.	*Lolium rigidum*	Darnel
15.	*Asclepias speciosa*	Milkweed
16.	*Bromus tectorum*	Downy brome
17.	*Bilderdykia Convolvulus*	Wild Buckwheat
18.	*Hordeum jubatum*	Wild barley

Long to very long (maximum length of dormancy exceeding 3 years):

19.	*Agropyron repens*	Couch grass, quack grass
20.	*Lappula echinata*	Blue bur
21.	*Lactuca virosa*	Dentate prickly lettuce
22.	*Avena fatua*	Wild oats
23.	*Atriplex hortensis*	Garden atriplex
24.	*Polygonum neglectum*	Knotweed
25.	*Atriplex hastata*	Hastata atriplex
26.	*Erucastrum gallicum*	Dog mustard
27.	*Peritoma serrulatum*	Indian pink
28.	*Taraxacum officinale*	Dandelion
29.	*Xanthium echina um*	Cocklebur
30.	*Sonchus arvensis*	Perennial sow thistle
31.	*Solanum triflorum*	Wild mustard
32.	*Helianthus aridus*	Wild sunflower
33.	*Thlaspi arvense*	Stinkweed
34.	*Lactuca Scariola*	Lobed prickly lettuce
35.	*Silene vulgaris*	Bladder campion
36.	*Sinapis arvensis*	Wild mustard
37.	*Sisymbrium altissimum*	Tumbling mustard
38.	*Axyris amaranthoides*	Russian pigweed
39.	*Spergula arvensis*	Corn spurry
40.	*Oenothera strigosa*	Evening primrose
41.	*Silene noctiflora*	Night flowering catchfly

42. *Cheirinia cheiranthoides*	Wormseed mustard
43. *Amaranthus graecizans*	Tumbleweed
44. *Amaranthus retroflexus*	Red-root pigweed
45. *Amaranthus blithoides*	Prostrate amaranth, prostrate pig-weed
46. *Corispermum marginale*	Bugseed
47. *Cyclachaena xanthifolia*	False ragweed
48. *Sophia multifida*	Flixweed
49. *Chenopodium album*	Lamb's quarters
50. *Plantago major*	Broad-leaved plantain
51. *Lepidium densiflorum*	Peppergrass
52. *Lepidium perfoliatum*	Perfoliate peppergrass
53. *Capsella Bursa-pastoris*	Shepherd's purse
54. *Grindelia perennis*	Gumweed
55. *Portulaca oleracea*	Purslane
56. *Medicago lupulina*	Black medic
57. *Monolepis Nuttalliana*	Spear-leaf goosefoot
58. *Convolvulus americanus*	Wild morning glory

Out of a total of 58 species, 6 had seeds whose life span in cultivated soil did not exceed one year and 18 had seeds that remained dormant in cultivated soil for periods not exceeding 3 years, except that a few of these had one or two seeds live past this period. None of these weeds, with the possible exception of *Salsola Pestifer* and *Cirsium arvense*, are particularly serious weeds, evidently because of their short longevity in cultivated soil. *Salsola Pestifer* is a serious weed in dry areas for reasons which will be pointed out later, whereas the seriousness of *Cirsium arvense* is due mainly to its persistent perennial habit of growth.

A number of species, in the neighbourhood of 22 to 28, depending on where the borderline cases are to be included, contained relatively few seeds that remained dormant in shallow depths in cultivated soil beyond a period of 3 years, and it is evident that these species could be controlled by suitable tillage practices. Approximately 30 of the species are shown to possess a particularly long period of dormancy in cultivated soil. Most of these latter species, wherever present in substantial numbers, constitute a very serious agricultural problem and for some of these no practical method is known at present that would effect their complete eradication.

It is seen from Table 4 that with most species there is a definite fluctuation in frequency of germination which tends to rise and fall in corresponding seasons throughout the whole life of the seeds. Table 4 has been prepared from average results obtained during 3 years after the initiation of each of the 3 series of experiments. The results of subsequent years are omitted in order to avoid a great amount of superficial detail, but it should be pointed out that the behaviour of the seeds following the 3-year period remained essentially the same.

The period of maximum or peak germination varied with the species and there was not a single period of the growing season when seeds of some species did not show a substantial emergence in the field. For the majority of the species studied, however, the peak of germination occurred within a relatively short period of about 3 weeks commencing about April 23,

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Bromus tectorum	1	0	489	179	84	9	4	3	5	1	3	50	7	8
	2	0	7	17	1	3	1	1	1	0	0	0	0	7
	3	0	1	0	1	0	0	0	0	0	0	0	0	0
Agropyron repens	1	0	280	800	172	34	15	11	12	3	3	2	4	1
	2	0	1	0	4	1	0	0	0	0	0	0	0	2
	3	0	0	5	2	0	1	0	0	1	0	0	0	3
Lolium rigidum	1	0	314	871	26	2	0	5	1	0	0	3	1	1
	2	0	32	18	1	1	0	0	0	0	0	0	0	0
	3	0	0	0	1	0	0	0	0	0	0	0	0	0
Hordeum jubatum	1	0	524	732	44	41	5	2	16	5	6	39	2	4
	2	0	4	1	1	0	0	0	0	0	0	3	0	0
	3	0	4	0	20	0	3	0	1	0	0	0	0	5
Avena fatua	1	0	105	455	52	27	5	104	31	1	3	16	0	0
	2	0	19	111	24	8	0	5	3	0	0	7	0	4
	3	0	0	0	20	0	5	0	0	0	0	0	0	8
Setaria viridis	1	0	0	1201	421	461	30	131	4	2	2	0	0	0
	2	0	0	0	0	2	3	1	0	0	0	0	0	0
	3	0	0	0	0	0	3	0	5	0	0	0	0	0
Rumex mexicanus	1	0	0	63	20	10	0	0	2	5	0	0	1	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	1	0	0	0	0	0	0	0	0
Polygonum neglectum	1	0	562	46	1	0	0	0	0	0	0	0	0	0
	2	0	64	1	1	0	0	0	0	0	0	0	0	0
	3	0	0	0	8	0	3	0	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Bilderdykia Convolvulus	1	0	851	661	315	8	2	7	5	0	0	0	0	0
	2	0	28	6	8	0	2	0	0	0	0	0	0	1
	3	0	0	1	1	3	0	0	0	0	0	0	0	0
Chenopodium album	1	0	441	21	370	11	9	6	1	0	0	0	1	0
	2	0	32	54	29	4	3	2	1	0	0	0	0	0
	3	0	64	191	58	26	39	17	0	3	1	0	0	0
Monolepis Nuttalliana	1	0	59	6	0	0	1	14	2	4	3	22	0	0
	2	0	1	0	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	13	1	0	0	0	0	0	11
Kochia trichophylla	1	0	315	40	3	2	0	8	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Corispermum marginale	1	0	0	86	77	46	8	217	10	0	0	0	0	0
	2	0	17	17	18	18	0	0	0	0	0	0	0	0
	3	0	0	0	107	24	37	21	7	0	0	1	0	0
Atriplex hortensis	1	553	700	34	1	0	0	2	0	0	0	0	0	0
	2	0	22	8	2	1	0	0	0	0	0	0	0	0
	3	0	3	0	35	0	0	0	0	0	0	0	0	0
Atriplex hastata	1	641	0	22	0	0	0	0	0	0	0	0	0	0
	2	1	53	6	0	0	0	0	0	0	0	0	0	0
	3	0	4	0	20	0	15	0	0	0	0	0	0	0
Axyris amaranthoides	1	0	855	41	60	10	13	3	0	0	0	0	0	0
	2	0	176	49	0	2	0	1	0	0	0	0	0	0
	3	0	15	78	50	0	13	1	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Salsola Pestifer	1	0	951	304	280	23	1	68	3	0	1	0	0	0
	2	0	0	0	3	2	0	0	0	0	0	0	0	0
	3	0	0	0	2	0	0	0	0	0	0	0	0	0
Amaranthus retroflexus	1	0	0	71	134	342	253	373	30	10	123	0	3	2
	2	0	0	2	5	27	3	3	0	6	0	0	0	5
	3	0	0	6	9	35	74	75	4	11	3	0	0	2
Amaranthus blithoides	1	0	0	108	1155	286	27	269	6	0	3	0	0	0
	2	0	0	32	45	15	2	7	1	0	0	0	0	0
	3	0	0	7	20	18	46	76	4	0	0	0	0	0
Amaranthus graecizans	1	0	1	36	20	358	92	315	25	1	2	0	0	0
	2	0	0	1	5	4	5	0	1	0	0	0	0	0
	3	0	0	2	1	4	76	28	0	0	1	0	0	0
Portulaca oleracea	1	0	0	0	0	0	182	23	78	14	190	0	11	1
	2	0	0	0	0	7	33	9	2	3	0	0	0	0
	3	0	0	0	0	0	247	30	17	0	1	0	0	0
Spergula arvensis	1	0	22	20	8	17	0	178	1	2	0	1	0	0
	2	0	0	0	0	13	2	9	4	1	0	0	0	0
	3	0	0	0	30	0	33	3	0	1	0	0	0	1
Agrostemma githago	1	49	495	48	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene noctiflora	1	0	142	171	2	21	0	333	2	6	5	0	0	0
	2	0	6	8	3	1	0	0	0	0	0	3	0	0
	3	0	0	0	282	0	31	0	2	0	0	0	0	1

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Silene vulgaris	1	0	208	119	8	13	0	144	20	4	0	4	6	0
	2	0	5	4	3	0	0	0	0	0	0	0	0	0
	3	0	0	0	30	0	21	1	0	0	0	0	0	2
Vaccaria vulgaris	1	0	1137	377	33	6	0	22	1	0	2	9	6	0
	2	0	8	7	0	0	1	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidium perfoliatum	1	12	63	3	38	4	1	4	0	0	6	135	54	11
	2	0	1	0	2	0	0	0	0	0	0	1	0	7
	3	0	1	2	0	4	0	0	0	0	1	27	0	103
Lepidium densiflorum	1	0	95	12	113	8	14	42	7	9	34	77	48	2
	2	0	44	10	5	0	5	0	1	0	0	17	0	5
	3	0	3	55	0	1	65	28	9	6	4	0	0	44
Thlaspi arvense	1	0	1101	133	212	88	4	268	7	4	5	5	1	0
	2	0	166	52	23	65	7	2	2	3	0	0	0	19
	3	0	21	24	123	37	37	10	0	0	0	0	0	1
Capsella Bursa-pastoris	1	0	0	5	0	3	2	0	34	5	2	0	9	0
	2	0	0	0	0	14	5	2	1	0	0	1	0	0
	3	0	0	0	8	0	35	1	0	0	0	0	0	0
Camelina sativa	1	758	432	0	0	2	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Camelina dentata	1	1591	232	2	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Camelina microcarpa	1	1210	155	4	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Neslia paniculata	1	591	0	30	1	22	0	18	1	1	0	0	0	0
	2	0	3	1	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Sisymbrium altissimum	1	0	790	26	139	4	1	3	0	0	16	0	31	0
	2	0	0	8	1	1	0	0	0	0	0	0	0	11
	3	0	132	121	11	11	14	24	1	0	1	0	1	9
Sophia multifada	1	0	45	4	28	13	1	23	0	2	2	113	9	0
	2	0	18	22	4	1	0	0	0	0	0	15	0	16
	3	0	0	14	1	0	3	7	2	0	0	29	13	45
Conringia orientalis	1	132	885	50	27	6	5	13	1	0	3	0	10	1
	2	0	7	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheirinia cheiranthoides	1	0	46	22	0	0	0	78	15	1	0	0	0	0
	2	0	3	1	1	1	0	1	1	0	0	4	0	0
	3	0	0	0	25	0	31	6	0	0	0	0	0	0
Sinapis arvensis	1	11	247	108	180	105	8	352	12	3	5	0	1	0
	2	0	19	38	3	6	1	1	1	6	0	2	0	3
	3	0	0	17	128	8	6	13	2	0	0	0	0	0
Erucastrum gallicum	1	0	157	7	15	47	2	130	19	7	1	1	1	0
	2	0	0	2	0	0	1	0	0	0	0	0	0	0
	3	0	0	0	0	0	21	7	0	1	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Brassica juncea	1	10	1025	95	16	13	0	62	2	1	0	0	1	0
	2	0	0	0	0	1	0	0	0	0	0	0	0	0
	3	0	0	0	4	0	1	0	1	0	0	0	1	0
Periloma serrulatum	1	0	815	77	0	1	0	1	0	0	0	0	0	0
	2	0	211	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	1	0	2	0	0	0	0	0	0	0
Medicago lupulina	1	0	0	11	21	0	1	3	4	1	1	1	0	0
	2	0	302	93	2	3	1	0	0	0	0	0	0	0
	3	0	0	0	45	0	7	0	1	0	0	0	0	0
Oenothera strigosa	1	0	0	136	10	5	1	17	20	0	0	0	0	0
	2	0	0	32	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	14	3	0	0	0	0	0	0
Asclepias speciosa	1	0	0	136	54	5	10	6	22	0	0	0	0	0
	2	0	0	2	7	0	0	1	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Convolvulus americanas	1	0	1	14	18	2	2	4	5	2	1	3	4	0
	2	0	0	6	11	0	0	0	0	0	0	0	0	0
	3	0	0	2	5	13	2	0	0	1	0	0	0	0
Lappula echinata	1	0	516	67	63	6	1	93	4	3	0	2	0	0
	2	0	3	4	0	0	1	0	0	0	0	1	0	1
	3	0	6	7	2	0	2	0	0	1	0	0	0	0
Solanum triflorum	1	0	21	126	2177	6	19	1	0	0	0	0	0	0
	2	0	0	70	58	9	3	2	0	0	0	0	0	0
	3	0	0	8	11	6	0	0	0	0	0	0	0	0

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Continued*

Species	Years after seeding	Numbers germinated during periods ending												
		April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
Plantago major	1	0	120	2	90	2	1	0	17	0	2	0	5	1
	2	0	0	1	6	5	0	14	1	0	0	0	0	0
	3	0	0	61	5	0	17	0	1	0	0	0	0	2
Cyclachaena Xanthifolia	1	0	84	36	10	0	0	0	0	0	0	0	0	0
	2	0	22	61	4	0	0	0	0	0	0	0	0	0
	3	0	1	25	12	5	1	0	0	0	0	0	0	0
Xanthium echinatum	1	0	52	351	5	4	0	11	2	0	0	0	0	0
	2	0	19	137	18	0	0	0	0	0	0	0	0	0
	3	0	0	0	5	0	0	0	0	0	0	0	0	0
Grindelia perennis	1	0	0	18	1	1	0	1	5	0	0	0	13	0
	2	0	34	5	3	11	0	0	0	0	0	16	0	8
	3	0	12	0	0	0	17	1	1	0	0	0	0	0
Helianthus aridus	1	0	872	164	538	4	1	2	0	0	0	0	0	0
	2	0	107	36	8	4	0	1	0	0	0	0	0	0
	3	0	1	11	17	0	3	0	0	0	0	0	0	1
Cirsium arvense	1	0	0	0	135	0	4	0	51	0	0	0	0	1
	2	0	0	1	2	1	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Tragopogon dubius	1	0	126	35	9	4	0	0	0	0	0	2	1	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Taraxacum officinale	1	0	0	8	23	2	11	0	35	0	1	30	33	2
	2	0	7	3	0	0	0	0	0	0	0	4	0	0
	3	0	0	0	0	0	2	2	0	0	0	0	0	3

TABLE 4.—PERIODICITY OF GERMINATION OF WEED SEEDS—*Concluded*

Species	Years after seeding	April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	September 15	September 30	October 31
		Numbers germinated during periods ending												
Lactuca Scariola	1	0	102	1	0	0	28	0	0	2	0	37	4	0
	2	0	5	5	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	5	0	0	0	0	0	0	0	0	3
Lactuca virosa	1	0	157	13	117	1	3	0	7	1	1	6	38	1
	2	0	12	14	19	2	0	0	0	0	0	0	0	0
	3	0	0	87	0	1	0	0	0	0	0	0	0	0
Sonchus arvensis	1	0	0	0	93	2	1	0	37	0	0	0	1	0
	2	0	0	1	5	1	3	1	0	0	0	0	0	0
	3	0	0	4	0	0	1	2	1	0	0	0	0	0

followed by general tapering off in germination until midsummer or fall. In some species, particularly the winter annuals, the second peak, though in the majority of cases not as pronounced as the first, occurred in the fall.

The periodic and regular recurrence of germination, common to the majority of the species, was about the same on clay, loam, and sandy loam soil and was not entirely dependent on the variation in the moisture content of the soil. As an illustration, large numbers of seeds germinated early during the relatively dry springs of 1938, 1940, and 1941, but rains occurring during the same period in 1939, 1942, and 1944 failed to induce greater numbers of seeds to germinate and the trends in the frequency of germination within this period during each of these years remained essentially the same.

It was thought that alternate freezing and thawing during the winter months might stimulate the relatively high germination in the spring. This is not equally effective on all the species, for some germinated in substantial numbers late in the spring, others only during the summer months, and still others only in the fall of the year. There were some species, on the other hand, whose germination was more or less haphazard and showed no marked or regular periodicity, but the proportion of such species was relatively small. For some, the period during which substantial numbers or the majority of seeds germinated, was very short, but for others substantial numbers of seeds continued to germinate throughout the whole or most of the growing season. For the great majority of the species, the period or periods of high germination were apparently determined at the outset so that any variations in the weather had little, if any, influence on the actual behaviour of the dormant seeds.

In considering periodicity of germination it was thought desirable to deal with the naturally dormant seeds that will not germinate, even under most favourable conditions, apart from those that are physiologically ready to germinate as soon as moisture and other factors become favourable. Freshly harvested seed usually contains the two classes of seeds in widely variable proportions. The periodicity of germination was therefore determined for freshly harvested seeds containing the two physiological classes and for seeds that had lain in the soil for at least a period of one year. The emergence data (Table 4) indicate that periodicity of germination throughout the year after ripening follows the same general trend as that for seeds that have lain in cultivated soil for one or more years.

The species investigated can be classed into several broad classes with respect to periodicity of germination, as follows:

Species germinated in greatest numbers early in the spring (April 23 to May 15): *Agrostemma githago, Camelina microcarpa, Camelina sativa, Camelina dentata, Kochia trichophylla, Tragopogon dubius, Conringia orientalis, Brassica juncea, Salsola Pestifer, Lolium rigidum, Bromus tectorum, Bilderdykia Convolvulus, Hordeum jubatum, Agropyron repens, Lactuca virosa, Lappula echinata, Atriplex hastata, Peritoma serrulatum, Xanthium echinatum, Thlaspi arvense, Helianthus aridus, Lactuca Scariola, Sisymbrium altissimum, Cyclachaena xanthifolia, Axyris amaranthoides, Chenopodium album, Plantago major.*

Species germinating in greatest numbers usually in mid-spring (May 7 to May 31): *Setaria viridis, Rumex mexicanus, Cirsium arvense, Asclepias speciosa, Solanum triflorum, Sonchus arvensis, Corispermum marginale, Oenothera strigosa, Convolvulus americanus.*

Species with peak germination occurring between late spring and mid-summer (May 31 to August 31): *Amaranthus blithoides, Amaranthus retroflexus, Capsella Bursa-pastoris, Amaranthus graecizans, Portulaca oleracea.*

Species germinating most readily in the autumn (Sept.–Oct.): *Sophia multifida, Lepidium perfolatium.*

Species not showing any regular or marked periodicity: Erucastrum gallicum, Taraxacum officinale, Silene vulgaris, Sinapis arvensis, Spergula arvensis, Silene noctiflora, Grindelia perennis, Medicago lupulina, Cheirinia cheiranthoides, Monolepis Nuttalliana, Lepidium densiflorum.

The data in Tables 2 and 3 indicate the vitality of weed seeds as well as their longevity in cultivated soil. The data indicate that the ratio of seeds that germinated and emerged to the total number of seeds is very low on the whole but that there is a wide variation between the individual species. In most cases not over 50% of the seeds emerged and in many of these not over 10% emerged. The low emergence of seedlings may be attributed to any of the following causes: (1) dormancy of seeds, (2) low viability of seeds to begin with, and (3) high mortality of seedlings before or immediately after emergence.

In view of the characteristic tapering-off of germination towards the conclusion of the experiment and in many cases complete cessation of germination long before the experiment was terminated, it is evident that the generally low proportion of emergence is not particularly due to dormancy of seeds but to one or both of the other causes. Tables 2 and 3 include some information on the viability of seeds as determined by germination tests in very shallow layers of moist sand in the laboratory. The differences between the number of viable seeds and the total number of seedlings that grew in the field indicate the approximate number of seedlings that died before or immediately after emergence. For many species, however, the experiment has not yet been completed and for these the percentage of seedling mortality is so far unavailable.

Seeds of species used in these experiments were sown in rows in the field in order to observe and record such growth habits as date of maturity and resistance to shattering. These characteristics have a very important bearing on the relative seriousness of weeds and, from the standpoint of weed control, are closely associated with the length of seed dormancy and distribution of germination during the growing season. The data obtained from this study are presented in Table 5 and will be referred to later.

Although it was possible to classify the weeds into certain broad categories with respect to length of dormancy, nature of germination, vitality, and other physiological characteristics of seeds, there were nevertheless great differences between the individual species. In fact, the behaviour of seeds of any species was typical only of the species itself and not actually of the broad class they represent. Because of such wide differences in the behaviour of seeds of individual weeds, even of the same general class,

TABLE 5.—AVERAGE DATE OF MATURITY AND RESISTANCE TO SHATTERING OF GRAIN CROPS AND WEEDS IN THE FIELD (1938–1942)†

Species	Date of maturity *	Relative resistance to shattering	Species	Date of maturity *	Relative resistance to shattering
Triticum vulgare (Thatcher)	Aug. 10	100	*Lepidium densiflorum*	July 24	25
Avena fatua (Banner)	Aug. 8	85	*Thlaspi arvense*	July 7	35
Hordeum vulgare (Prospect)	July 26	95	*Capsella Bursa-pastoris*	July 15	35
Bromus tectorum	July 22	50	*Camelina sativa*	July 18	40
Agropyron repens	July 22	65	*C. dentata*	July 18	40
Lolium rigidum	Aug. 12	40	*C. microcarpa*	July 26	40
Hordeum jubatum	July 15	65	*Sisymbrium altissimum*	Aug. 7	40
Avena fatua	July 18	30	*Sophia multifida*	July 22	25
Setaria viridis	July 31	25	*Conringia orientalis*	July 23	45
Rumex mexicanus	July 18	65	*Cheirinia cheiranthoides*	Aug. 8	35
Polygonum neglectum	Sept. 25	55	*Sinapis arvensis*	July 21	40
Bilderdykia Convolvulus	Aug. 1	45	*Erucastrum gallicum*	July 31	40
Chenopodium album	Aug. 28	40	*Brassica juncea*	July 31	40
Monolepis Nuttalliana	Aug. 4	35	*Peritoma serrulatum*	Aug. 12	45
Kochia trichophylla	Sept. 13	45	*Medicago lupulina*	July 20	35
Corispermum marginale	Sept. 7	35	*Oenothera strigosa*	Aug. 16	40
Atriplex hortensis	Aug. 25	40	*Convolvulus americanus*	July 31	45
A. hastata	Aug. 16	40	*Solanum triflorum*	July 22	85
Axyris amaranthoides	Sept. 3	35	*Plantago major*	Aug. 15	25
Salsola Pestifer	Sept. 28	70	*Cyclachaena xanthifolia*	Sept. 8	45
Amaranthus retroflexus	Aug. 8	30	*Xanthium echinatum*	Aug. 19	85
A. blithoides	Aug. 10	35	*Grindelia perennis*	Sept. 20	40
A. graecizans	Aug. 22	35	*Helianthus aridus*	July 29	55
Portulaca oleracea	Aug. 2	25	*Cirsium arvense*	Aug. 12	50
Spergula arvensis	July 20	30	*Lappula echinata*	July 25	45
Agrostemma githago	Aug. 11	55	*Tragopogon dubius*	July 26	10
Silene noctiflora	July 24	30	*Traxacum vulgaris*	July 5	10
S. vulgaris	July 26	40	*Lactuca Scariola*	Aug. 10	25
Vaccaria vulgaris	July 24	40	*L. virosa*	Aug. 10	25
Lepidium perfolatum	July 22	35			

† Weeds were sown in rows 1 foot apart soon after ripening and grain crops were sown as soon as conditions for seeding became favourable the following spring.
* First seeds ripened and able to shatter. Grain crops ready to be cut with a binder.

it was thought appropriate to record the results of these experiments for each weed separately. The results obtained from the 3 series of experiments are treated together, however, to avoid undue repetition. The individual species are dealt with in order from the shortest to the longest average length of dormancy of seeds.

SPECIES WITH NONE TO VERY SHORT PERIOD OF SEED DORMANCY

Agrostemma githago (Table 4) shows no prolonged dormancy of seeds, all of which germinate early in the spring and within a period of one month. The data substantiate those of Muencher (11) and indicate that seeds can be plowed under to prevent immediate or subsequent emergence. The weed is a winter annual and as such gives trouble chiefly in winter crops. Because of early germination, field infestations can be prevented by delaying spring seeding until after-growth of seedlings have been destroyed.

Camelina microcarpa, *C. sativa*, and *C. dentata* all behave in much the same manner in the field (Table 4). They have a relatively short period of seed dormancy and seeds buried not deeper than 3 inches germinate

or rot before the end of June. Well over 95% of the seeds germinate particularly early in the spring, and because of this, may be induced to germinate early and be destroyed by tillage before spring crops are sown. Some plants of all three species behave as winter annuals and are therefore more serious in winter grains, particularly where tillage fails to destroy all existing plants. These weeds should not be a serious problem under clean cultivation. They are particularly common in poorly cultivated fields and in waste places where they are allowed to mature and shatter seeds (Table 5).

Kochia trichophylla (Fig. 1A) is an ornamental plant that has escaped cultivation, but apparently due to low degree of dormancy of seeds has never become a very serious weed. The great majority of the seeds germinate very early in the spring (Table 4) and the rest remain dormant for a period not exceeding 2 or 3 months.

Tragopogon dubius (Fig. 1B) has a maximum period of seed dormancy not exceeding one year. As with other weeds of this class, one year of clean, ploughless fallow should rid the land completely of dormant seeds. Due to low degree of seed dormancy, it is not a serious pest, and likely never will be in cultivated fields. It thrives well along roadsides, ditch banks, and abandoned fields were weeds are not destroyed.

Species with Short to Intermediate Average Period of Seed Dormancy

Conringia orientalis (Fig. 1C) and *Brassica juncea* (Fig. 1D). A few seeds of these two weeds live in shallow depths in cultivated soil for periods greater than one year (Tables 1, 2, and 3). Heavy infestations in crops succeeding fallow seldom occur, evidently because of low degree of dormancy of seeds. Their prevalence is often limited to edges of fields and roadsides where seedlings are not destroyed by cultivation. Seeds of these weeds shatter readily (Table 5) and germinate in large numbers early in the spring (Table 4). Heavy infestations can therefore be destroyed before a spring crop is sown.

Two seeds of *B. juncea* out of a total of over 5000 germinated in the fourth year after seeding. In order to find out if this extreme length of dormancy is transmitted to the progeny or not, the seedlings were allowed to reach maturity and 200 seeds tested for dormancy in the laboratory. All viable seeds germinated within one year, indicating that the exceptionally long period of dormancy of these seeds was not transmitted to the progeny.

Salsola Pestifer (Fig. 1E) shows a rather short period of dormancy for the great majority of the seeds, on an average not over 0.5% germinating in the second year and only 2 out of a total of over 5000 having been found to live near the soil surface for 3 years. In spite of its low dormancy *S. Pestifer* is very widespread in dry regions. This is due to characteristics other than dormancy of seeds. At maturity *S. Pestifer* breaks off at the base and blows away, scattering seeds as it travels with the wind. Wherever a thick stand of this weed is found, however, the plants are held together and do not blow away readily, and because seeds hardly shatter when the plants are not blown about, their vitality is preserved for many years. Such infestations serve as a continual source for soil pollution,

unless plants and seeds are destroyed by ploughing or burning. Ploughing to bury all the seeds deeply in the soil where they will not rot away without emerging has generally produced clean crops, but this treatment has some disadvantages. Burning is likewise effective but is dangerous in areas subject to erosion.

The great majority of *S. Pestifer* seeds lying on or just below the ground germinate early in the spring (Table 4). In controlling this weed advantage should be taken of this characteristic by allowing the seeds to germinate and destroying the seedlings before the crop is sown. It must be borne in mind, however, that unless all seeds are in contact with the soil, germination will be incomplete and tillage to destroy the seedlings prior to seeding may bring more seeds in contact with the soil where they will germinate and spring up in a crop. Ploughing under to bury the seeds, or to place them in a position where they will germinate and later be destroyed by tillage, should be a satisfactory method of eradicating this species, provided plants are not allowed to reach maturity and are not carried in from infested areas by the wind.

Vaccaria vulgaris (Fig. 1F) shows a comparatively low degree of seed dormancy. In the samples chosen for investigation 97% of the viable seeds germinated during the first year after seeding, 3% during the second, and only one seed out of a total of over 5000 germinated in the third year. Because of low dormancy of seeds, the weed, though widespread, does not persist in great numbers in cultivated fields.

Setaria viridis (Fig. 1G) has a relatively short period of seed dormancy, well over 98% germinating during the first year from shallow depth in the field (Tables 1, 2, and 3). The seeds do not germinate very early in the spring (Table 4) and for this reason heavy infestations may occur in early sown spring crops. The weed could be controlled by delaying the final shallow cultivation until after June 15 and then seeding the land to some early maturing crop such as barley. A clean summerfallow should be particularly effective in destroying heavy infestations of this weed.

According to Muencher (11) the seeds will not germinate in the fall of the year in which they are produced, but remain dormant until the following spring. The data presented herewith (Table 4) indicate that all seeds, those that have lain in cultivated soil for more than a year as well as newly shattered seeds, behave in this manner, for none have been observed to germinate after August 31 and only 4 out of a total of 2266 after July 31.

Rumex mexicanus (Fig. 1H) and *Cirsium arvense* (Fig. 1I) have seeds that possess a relatively short period of dormancy, though some may live in cultivated soil without germinating for 2 or 3 years. There is relatively little danger of these weeds persisting from seed infestations, but the problem with *Cirsium arvense* is due to the persistence of its perennial root system against cultivation and also against competition from other plants. *R. mexicanus* on the other hand, is not a serious weed, for its perennial roots can be readily destroyed by cultivation.

The seeds of both of these weeds germinate most readily in mid-spring (Table 4). The viability of seeds of both species was particularly low, for not over 5% of the seeds that were planted germinated (Table 3).

Lolium rigidum (Fig. 1J) shows a comparatively short period of dormancy of seeds, the majority of which grow or lose their viability in the soil within a year. Clean fallow should be quite effective in ridding the soil of most of the seeds. The majority of the seeds, if in contact with the ground, germinate early in the spring, that is, before May 15 (Table 4), and these could be destroyed before a spring crop is sown.

Asclepias speciosa (Fig. 1K) shows a period of seed dormancy not exceeding 2 years, although 95% or more of the seeds germinate during the first year. The seeds germinate in greatest numbers between May 7 and May 31 (Table 4), though fairly substantial numbers continue to germinate till about July 31, after which date germination ceases.

Bromus tectorum (Fig. 1L) seeds showed a variable period of dormancy in the samples chosen for investigation, although none lived at shallow depths in soil beyond a period of 3 years. The 1937 seeds all germinated and lost their viability in soil within a year (Table 1), but substantial numbers of the 1938 seeds, ranging from 25 to 50% of the total numbers that germinated, grew in the second year (Table 2). Less than 2% germinated during the third year after seeding.

Bromus tectorum seeds, if in contact with the ground, germinate in large numbers early in the spring (Table 4) and this behaviour can be taken advantage of by inducing the majority of the seeds to germinate and destroying the seedlings before a crop is sown. Substantial number of seeds also germinate in the fall and those plants that show a winter annual habit of growth will therefore survive into the next year, unless they are destroyed by cultivation. This weed produces seeds in abundance and from the standpoint of seed characteristics, has the potentiality of a moderately serious annual weed.

Bilderdykia Convolvulus (Fig. 1M) contains well over 95% of seeds that germinate during the first year and none remain viable in soil beyond a period of 3 years. The weed should be easily controlled by clean cultivation, but the difficulty is that the seeds are not much smaller than those of wheat and are therefore very difficult to remove from the grain. The seeds germinate in greatest numbers early in the spring (Table 4), hence many seedlings can be destroyed before a crop is sown.

Species with Long to Exceedingly Long Period of Seed Dormancy

Hordeum jubatum (Fig. 1N) and *Agropyron repens* (Fig 1O), though listed under two different classes with respect to period of seed dormancy, show little actual difference, the former falling at the bottom of one class (life in cultivated soil up to 3 years), the latter at the top of the next class (life in soil exceeding 3 years). Actually, seeds of *H. jubatum* originating in 1940 showed slightly longer average period of dormancy than those of *A. repens* (Table 3), though the reverse was true for seeds of the other two years (Tables 1 and 2). The seeds of the two species likewise differ little with respect to periodicity of germination, the peak germination in both occurring between April 23 and May 15 (Table 4).

Lappula echinata (Fig. 1P) does not indicate a particularly long average period of dormancy of seeds, 95% of which germinate during the first year. Clean summerfallow to rid the land of fresh infestations of seeds should be

very effective in ridding the soil of weed seeds. The great majority of the seeds, if in contact with the ground, germinate very early in the spring (Table 4) and these can be destroyed before a crop is sown.

Avena fatua (Fig. 1R). The seeds show a maximum period of dormancy of 3 to 4 years. The maximum period of dormancy is actually about one year shorter than for *Lappula echinata* but the percentage of seeds germinating in the second and third years is substantially greater. In these experiments, about 80% of the viable seeds germinated during the first year, 18% during the second, 2% in the third, and 2 seeds out of several thousands in the fourth year. Seeds originating from the secondary florets of a spikelet show greater tendency to dormancy than the larger seeds originating at the base of the spikelet. Cultivation to induce the seeds to germinate, followed by destruction of the seedlings, should be quite effective in ridding the soil of many seeds. The great majority of the seeds, if buried at shallow depths in the soil, germinate in May (Table 4) and these could be destroyed before a crop is sown. Contrary to most other weeds, wild oats seeds will not germinate readily when lying on the surface of the ground. It is essential therefore to work the land early, preferably immediately after the crop is removed to bury the seeds at a depth where they will most readily germinate.

Atriplex hortensis (Fig. 2A) and *A. hastata* (Fig. 2C) each have two distinct morphological types of seeds, type A exhibiting virtually no delayed germination and type B showing very marked longevity in cultivated soil. In *A. hortensis*, type A seeds are flat, light brown, about 3 mm. in diameter, usually enclosed in bracts at maturity. Those of type B are smaller but of variable size ranging from 1 to 2 mm. in diameter, more spherical, dark brown or black, usually without bracts or bracts falling off at maturity. *A. hastata*, on the whole, has much smaller seeds than *A. hortensis*. Seeds of type A are 1.5 to 2 mm. in diameter, flat and dark brown; those of type B are 0.5 to 1 mm. in diameter, black, and more spherical than those of type A.

The two types of seed were separated in samples originating in 1938, 1939 and 1940 and were subjected to repeated germination tests in the laboratory until no more would germinate. The following are the average results obtained:

Species	Type A seeds		Type B seeds	
	Viable seeds germinating within 6 months	Germinating after 6 months	Viable seeds germinating within 6 months	Germinating after 6 months
	%	%	%	%
A. hortensis	100 0	0	11.7	88.3
A. hastata	100 0	0	9 8	90.2

Seeds of type B were subjected to repeated germination tests for 3 years but so few germinated during this period that it was decided to treat them with concentrated sulphuric acid in order to disintegrate the

outer seed coat to facilitate germination. The seeds were immersed in the acid for 15 minutes, after which treatment all viable seeds germinated immediately.

There were about equal proportions of the two types of seeds in the samples examined. If *Atriplex* possessed type A seeds only, it would be classed as a species showing little or no seed dormancy, but if it had type B seeds only, the state of dormancy would be of the highest order.

No attempt was made to separate the two types of seed in field experiments, hence the results obtained on the length of dormancy indicate an approximate average for the mixture of these two types. The data indicate that some seeds, evidently belonging to morphological type B, are capable of remaining dormant in cultivated soil for at least a period of 5 years, but it is evident that the maximum length of dormancy for some of the seeds is greater than this period. Of the weeds so far considered in this report, *Atriplex* spp. are the first whose maximum period of dormancy extends beyond a period of 5 years.

Polygonum neglectum (Fig. 2B) has a substantial proportion of seeds germinating after lying in cultivated soil for more than 1 year. The maximum concentration of germination occurs within a limited period between April 23 and May 15 (Table 4). No germination occurs under any circumstance after June 30.

Erucastrum gallicum (Fig. 2D) possesses seed dormancy similar to that of *Polygonum neglectum*, but does not show the same regular nor marked periodicity of germination. Most of the seasonal emergence occurs between April 23 and July 15 (Table 4), but no definite peak of germination is evident in this species. A few seedlings continue to emerge right through till the end of September.

Peritoma serrulatum (Fig. 2E) has a particularly high proportion of seeds germinating after lying in cultivated soil for a year. The seeds have a very sharp peak of germination occurring between April 23 and May 15 (Table 4), and no seeds germinate after July 15.

Taraxacum vulgaris (Fig. 2F). The samples obtained for experiment show a maximum period of seed dormancy of only 4 years, but the proportion of viable seeds germinating during the third and the fourth years is much higher than in any of the species so far considered, including those having some seeds that germinate during the fifth year. The average period of seed dormancy, as determined, is therefore higher for this than for any of the other species so far discussed. The seeds show no regular or marked periodicity of germination (Table 4).

Xanthium echinatum (Fig. 2G), has a few seeds germinating during the fifth year after seeding (Table 3) and it is likely that some will survive even beyond this period. The peak of germination occurs between May 1 and May 15 (Table 4), though emergence of relatively few seedlings continues till about the end of July, after which date seeds do not germinate until the following spring.

Sonchus arvensis (Fig. 2H) and *Lactuca Scariola* (Fig. 2L) have little in common except that seeds of both exhibit an approximately equal relative length of dormancy in cultivated soil. Seeds of *S. arvensis* begin

germinating usually in mid-spring with a considerable proportion of seedlings appearing till about the end of July (Table 4). *L. Scariola* begins germinating on the whole about 2 weeks earlier and, in addition to its peak germination in the spring, has the second peak, though not as pronounced as the first, occurring in the fall (Table 4). The tendency of seeds to germinate in the fall appears to be typical of most winter annuals. *L. Scariola* appears to possess seeds of greater relative period of dormancy than *L. virosa* (Fig. 1Q), though this may be due to the difference between the two samples of seed used rather than the general rule.

Seeds of *S. arvensis* and *L. Scariola* on the whole possess a relatively low viability of seeds (Tables 2 and 3).

Solanum triflorum (Fig. 2I) and *Helianthus aridus* (Fig. 2J) show longevity in cultivated soil similar to that of *Sonchus arvensis*, but the behaviour of the seeds with respect to seasonal germination is very different in each case. The seeds of *S. triflorum* germinate in greatest numbers between May 1 and May 31 and none after July 31 (Table 4). Those of *H. aridus* have their peak germination earlier in the spring and as with *S. triflorum* seldom germinate after July 15.

Thlaspi arvense (Fig. 2K). The data indicate that few, if any, seeds live in cultivated soil beyond a period of 6 years. Substantial numbers in most samples, however, germinate throughout the first 4 years after seeding. This characteristic behaviour is typical of the most serious annual weeds, for no treatment however effective in suppressing or destroying the vegetative growth would be at all effective in destroying the seeds that are already present in the soil, unless such treatment is continued for many years.

Much and sometimes the largest proportion of the seasonal emergence of *T. arvense* occurs before the middle of May (Table 4) and this could be destroyed before a crop is sown. However, many other seedlings continue to emerge after this date and right through to the end of the growing season. The growth of the weed in a crop is therefore liable to be heavy unless a thick vigorous stand of the crop is established before many weeds emerge.

The data indicate (Table 5) that seeds of this species mature and shatter long before a grain crop is harvested. This is a serious characteristic and is undoubtedly largely responsible for such widespread occurrence of the weed.

Silene vulgaris (Fig. 2M) and *Sinapis arvensis* (Fig. 2N) have substantial numbers of seeds that germinate from cultivated soil throughout the first 4 years after seeding and longevity of the remaining seeds extend for at least 6 years. The seeds germinate in large numbers early in the spring (Table 4) but, as with *Thlaspi arvense*, a substantial proportion of them continue to germinate after this period and right through until fall. Both weeds produce seeds in abundance which mature and shatter in large numbers before crops are harvested (Table 5). From the standpoint of volume of seed production, seed dormancy, periodicity of germination, and seed shattering, these species have characteristics of particularly serious weeds.

Sisymbrium altissimum (Fig. 2O). Relatively few seeds of this species remain dormant in cultivated soil for periods greater than 6 years. The peak of germination occurs early in the spring (Table 4) and this aids in destruction of large numbers of seedlings before a crop is sown. As indicative of all winter annuals, another peak of germination, though not as pronounced as the first one, occurs in the fall.

The weed is a very prolific seeder, but seedlings are so tender that many, perhaps the great majority, die before growth is finally established. Unlike those of *Sinapis arvensis*, the seedlings cannot stand much competition with a cereal crop, although they can compete somewhat more successfully in dry years.

Axyris amaranthoides (Fig. 2P) has two distinct morphological types of seed, type A exhibiting little delayed germination and type B showing very marked longevity in cultivated soil. Type A seeds are oblong, tapering at the base, brown, with surface minutely wrinkled and giving a speckled appearance, and a distinct ear or wing on the upper end. Those of type B are somewhat smaller, oval to almost round, greyish, with a smooth surface exhibiting a silky lustre.

The two types of seed were separated in samples originating in 1937 to 1940, inclusive, and subjected to repeated germination tests in the laboratory for a period of 4 years. The following are the results obtained:

GERMINATION OF TYPE A AND TYPE B RUSSIAN PIGWEED SEEDS IN MOIST SAND IN THE LABORATORY

Seeds germinating in	Type A		Type B	
	Viable seeds germinating within		Viable seeds germinating within	
	6 months	2 years	6 months	3 years
	%	%	%	%
1937	77.6	100.0	0	14.3
1938	98.5	100.0	0	0
1939	84.6	100.0	0	0
1940	92.9	100.0	0	31.8

The majority of type A seeds germinated immediately, that is, within 2 weeks after being placed in a layer of moist sand 1 cm. thick. None of these seeds remained viable in moist sand beyond a period of 2 years and in fact all but those of 1937 germinated within 12 months from the start of the test. None of type B seeds, on the other hand, germinated within 1 year of exposure in moist sand and only 14 out of a total of 800 germinated within a 3-year period, those germinating belonging to the 1937 and 1940 lots. At the end of the 3-year period type B seeds were immersed in concentrated sulphuric acid for 15 minutes as a result of which treatment all the seeds that remained viable germinated immediately. It is believed, however, that many and perhaps the majority of the seeds, which might have in time germinated in moist sand, were killed by the acid treatment.

If so, the percentage in the second column under type B seeds would even be lower than indicated, since germination percentage is based on the total germination and not on the numbers of seeds taken for experiment.

In field tests, no attempt was made to separate the two types of seed, hence the results obtained indicate average results for the mixtures in question. In the samples examined, the proportion of type A seeds was found to vary from 54 to 71%.

Field data (Table 2) indicate that many seeds, evidently belonging to morphological type B, are viable after lying in cultivated soil for 6 years. From the standpoint of weed control this is a serious characteristic, but it is compensated by other factors that appear to reduce considerably the seriousness of the weed. The proportion of highly dormant seeds to the total number is relatively small. In addition, it possesses a very sharp peak of germination occurring before May 15 (Table 4), thus facilitating the destruction of a great proportion of total seasonal emergence of seedlings before a crop is sown. Furthermore, seeds mature quite late in the season (Table 5), thus the crop and the weeds are often cut and removed before any weed seeds shatter. For this reason, the weed thrives better along edges of fields, roadsides and waste places where plants are less likely to be destroyed before maturity.

Spergula arvensis (Fig. 2 Q) and *Silene noctiflora* (Fig. 3A) both show very long dormancy of seeds. They are very prolific seeders and mature and shatter large quantities of seeds before a crop can be harvested (Table 5). They appear to have many characteristics of serious annual weeds. Both show marked fluctuations in germination, but do not show any regular periodicity of germination (Table 4). The largest proportion of season emergence occurs between April 23 and July 31. The lack of a definite cycle of germination renders them difficult to cope with, for no definite tillage or cropping practice can be expected to produce the same effect in every year.

Oenothera strigosa (Fig. 2R) though possessing a high degree of seed dormancy, is a biennial and as such is not a serious weed in cultivated crops. Large numbers of seeds begin to germinate in mid-spring (Table 4), though a fair proportion of them continue to germinate till about July 31, after which date germination ceases. This species is the first case of a weed possessing highly dormant seeds but giving little trouble in cultivated fields, the reason for this being the biennial habit of growth.

Cheirinia cheiranthoides (Fig. 3B) has seeds capable of remaining dormant in cultivated soil for many years and hence has potentialities of a serious annual or winter annual weed. It possesses a few characteristics that facilitate its control in spring crop areas. Though some seeds germinate about the time the crops are sown, large numbers germinate later in the season (Table 4) and as seedlings are particularly small and fragile in the early stages of their development, they are readily suppressed by a vigorous crop. The period of emergence to ripening for this species is about the same as for wheat (Table 5); therefore the great proportion of weed seeds may be gathered up with the grain before they have had a chance to shatter. Apparently, because of these habits, it is more common along roadsides and waste places than in well cultivated fields.

Amaranthus graecizans (Fig. 3C), *A. retroflexus* (Fig. 3D), and *A. blithoides* (Fig. 3E) all possess very long dormancy of seeds, many of which do not "grow out" from shallow depths in the soil within 6 years. The seeds of all three possess a very thick, hard coat which is permeable to water but remains dense and brittle in the soil for many years, even after the embryo has split it open when germinating.

Fortunately these species are not as serious as the period of seed dormancy might indicate, mainly because of one outstanding feature. The seeds, particularly of the latter two species, do not germinate in appreciable numbers until late spring or summer (Table 4) and by that time the crops have made considerable growth and are able to compete successfully with any weeds that might emerge. They often become serious pests where competition from crop is poor or lacking, such as in gardens or edges of cultivated fields. They do not mature seeds early (Table 5) but often grow and produce large supplies of seed in stubble after the crop is removed. They are particularly prevalent on fallowed land, for they emerge in large numbers after other weeds have ceased to germinate, thus necessitating additional tillage to keep them down. Where such growth is light, farmers are inclined to leave the summerfallow unworked and through such procedure—or lack of procedure—allow a few plants to produce large numbers of seeds. It must be pointed out that all three, if allowed to reach maturity, produce abundant numbers of highly viable seeds (Tables 2 and 3).

Corispermum marginale (Fig. 3F) has a very long period of dormancy in cultivated soil but for some reason yet unknown does not cause serious damage to cultivated crops, except on sandy soils. It thrives particularly well in dry conditions, and on soils subject to wind erosion has perhaps been as great an asset as a liability by being able to cover the surface and protect it from the ravaging effects of the wind. It begins germinating usually in mid-spring and keeps on germinating in substantial numbers till about July 31 (Table 4).

Cyclachaena xanthifolia (Fig. 3G) is another case of not exceptionally serious weed possessing a high degree of seed dormancy. It matures late in the season (Table 5), thus facilitating its removal along with the crop before any seeds shatter on the ground. Plants along the edges of the fields, however, are not often destroyed and reach maturity. Hence, this species is found more generally along roadsides and edges of fields than in cultivated crops. The seeds germinate in large numbers early in the spring and these can be destroyed before the crop is sown. No germination has been observed to take place after June 30 (Table 4), hence tillage to facilitate fall germination would be futile.

Sophia multifida (Fig. 3H) has many characteristics of a serious annual weed. It has an especially long period of dormancy of seeds, germinates in large numbers just about the time the crops are sown (Table 4) is a prolific seeder, matures early and shatters readily (Table 5). It is a very common weed in western Canada and will no doubt continue to be so for a long time, for no program however effective in destroying or suppressing the growth of the weed will be at all effective in destroying the seeds that are already present in the soil. The weed cannot compete with grain crops quite like *Sinapis arvensis*, for example, and where feasible can be

controlled by heavy seeding of grain and by use of commercial fertilizers (9). It germinates in large numbers in the fall (Table 4) in which case the seedlings must be destroyed before the next crop is sown.

Chenopodium album (Fig. 3I) has many seeds of comparatively long periods of dormancy in cultivated soil and is a prolific seeder. It is therefore a serious weed once the soil becomes heavily polluted with weed seeds. It has certain characteristics, however, that tend to prevent soil pollution and because of these the weed is only of secondary importance to such annual weeds as *Avena fatua*, *Sinapis arvensis* and *Thlaspi arvense*, all of which shatter large quantities of seed before the crop is harvested. Unlike these weeds, *C. album* matures rather late in the season (Table 5) and the weed can be harvested along with a crop before many weed seeds have had a chance to shatter. The weed often grows and develops in stubble after the crop is cut, hence cultivation immediately after harvest is essential for its control. Where land is heavily polluted with weed seeds, relatively large numbers of seedlings can be destroyed before a crop is sown, for these begin germinating early in the spring (Table 4). However, the destruction of weeds before seeding is in itself not an assurance of a clean crop for as in the case of *Thlaspi arvense* and *Sinapis arvensis*, comparatively large numbers continue to emerge well into the month of July. Where feasible, fertilizing to produce a vigorous crop that would compete effectively with the weed, is a useful practice (9).

Plantago major (Fig. 3J) indicates a very long period of dormancy of seeds. It is, however, not a very serious weed in Canada. The weed possesses a relatively shallow perennial tap root that is readily destroyed by cultivation, usually before seeds are produced. It is therefore common in old pastures, meadows, lawns and waste places and is more prevalent in humid than in dry regions. *P. major* begins to germinate early in the spring, but a fair proportion of seeds continue to germinate throughout most of the growing season (Table 4).

Lepidium densiflorum (Fig. 3K) and *L. perfoliatum* (Fig. 3L) have certain common physiological as well as botanical characteristics. Seeds of both possess great longevity in cultivated soil, both are very prolific seeders, reach maturity early (Table 5), and shatter large quantities of seed before the crop is cut. *L. densiflorum* is very common in Canada and is responsible for substantial reductions in crop yields. It does not compete successfully with a really vigorous crop, however, and methods that favour rapid development of the crop have a definite advantage in suppressing this weed. *L. densiflorum* germinates at a more or less uniform rate throughout the whole of the growing season (Table 4).

L. parfoliatum was recently introduced from Europe and is spreading rapidly. It is potentially even more serious than *L. densiflorum* for it is taller, develops more rapidly, and competes more effectively with grain crops. Its peak germination occurs in the fall (Table 4), and since it is a winter annual it is essential that this late fall growth be destroyed before the next crop is sown.

Capsella Bursa-pastoris (Fig. 3M) does not appear to have a large proportion of seeds remaining dormant in cultivated soil beyond a period of 5 years, but does indicate a comparatively high emergence in the third

and fourth years. For a prolific and early seeder (Table 5) this is a serious characteristic, but in spring crop areas it has one drawback that forces it to fall into a class of secondary economic importance. It has a peak germination occurring in the late spring or summer (Table 4), hence its emergence coincides with a period when crops have generally become well established and able to compete successfully with this weed. It is therefore more common in areas that offer less competition to its development, such as in gardens, farmyards, and uncultivated fields.

Grindelia perennis (Fig. 3N) has a high degree of dormancy of seeds, but is a biennial or a short-lived perennial that readily succumbs to clean cultivation methods. Because of this habit of growth, it is unable to produce seeds before plants are destroyed by tillage. It is therefore a weed common to the native prairie, roadsides and uncultivated fields. *G. perennis* does not appear to possess any marked or regular periodicity of germination (Table 4).

Portulaca oleracea (Fig. 3O) has a very long period of natural seed dormancy so that land once infested with it may be expected to remain infested for many years, even under clean cultivation. It cannot compete successfully with spring grain crops, however, but is common mostly in gardens and orchards that offer less competition for its development. The plants are small and seedlings do not emerge until after June 15 (Table 4) by which time grain crops have made considerable growth to enable them to smother it completely. *P. oleracea* grows and matures late in the season (Table 5), hence it is important to continue removing and destroying all young plants until fall.

Medicago lupulina (Fig. 3P) like other members of *Medicago* contains some hard seeds that are capable of remaining dormant in cultivated soil for many years. It does not appear to reduce the yield of grain crops considerably, however, and thrives more commonly on somewhat infertile soils. *M. lupulina* has a distinct peak of germination which is not particularly regular in its occurrence (Table 4). A fair proportion of seedlings, however, occur throughout most of the growing season.

Monolepis Nuttaliana (Fig. 3Q), like *Chenopodium album* with which it is distantly related, possesses a comparatively high degree of dormancy of seeds, many of which germinate only after lying in soil for 4 or 5 years. The plants are low and do not appear to offer much competition to growing crops. This weed possesses no marked or regular periodicity of germination (Table 4). It matures relatively late in the season (Table 5) and for this reason does not shatter many seeds before the crop is cut.

Convolvulus americanus (Fig. 3R) has hard seeds that remain viable in soil for long periods and only a small proportion of which germinate in any one year. In one experiment (Table 1), 88.7 per cent of the viable seeds lay at shallow depths in cultivated soil for 3 years without germinating. In another experiment (Table 2) 55.2% of the total numbers that germinated lay dormant in the soil for 6 years. It is evident that the maximum period of dormancy in cultivated soil is much greater than 6 years. As in all species containing hard seeds, emergence of seedlings appears throughout most of the growing season, although in this species the peak of germination occurs in mid-spring (Table 4).

DISCUSSION

The data obtained from this investigation indicate that weeds differ greatly with respect to germination and habits of growth. It can be concluded therefore that no method of attack, however effective on one weed, would be equally, if at all, effective on another. For the man on the land this complicates the problem considerably for very few cases can be cited where the weed problem is due entirely to some one particular weed.

The relative seriousness of a weed is due principally to any one or several of the following characteristics:

Period of dormancy of seeds.
Distribution of germination throughout the growing season.
Viability of seeds.
Quantity of seeds produced.
Date of maturity.
Resistance to shattering.
Method of seed distribution.
Ability to compete with growing crops.
Persistance of perennial roots under cultivation.

Detailed information with respect to the first three characteristics is presented in this paper for 58 of the most common species. Somewhat more limited information is also presented on date of maturity and shattering quality, both of which are closely associated with the period of seed dormancy and nature of seasonal germination. Consideration of the remaining factors is beyond the scope of this paper. The point that is brought out clearly from this investigation is that dormancy of seeds, though not entirely responsible for the seriousness of a weed, is nevertheless one of the most important factors. Of all annual weeds presenting real economic difficulty only one, *Salsola Pestifer*, possesses a relatively short period of dormancy of seeds. This weed, though serious in dry regions, is relatively easy to control. Its seriousness is as much, if not more, due to its rapid growth and development in stubble *after* a crop is removed, as to direct competition with the growing crop. Its widespread occurrence is due principally to its high drought resistance and particularly rapid distribution by the wind.

There is no practical method known at present that will eradicate weeds of relatively long period of dormancy of seeds. Where weeds of this nature are encountered, it is evident that stress should be laid on tillage and cropping practices that favour the growth of the crop and suppress the vigour and density of the weeds rather than on methods that are designed to destroy the weed seeds in the soil. The summerfallow, which is particularly effective in destroying weed seeds of relatively short period of dormancy, can be regarded as only partially effective or entirely inadequate on seeds of long period of dormancy. This is because clean summerfallow, though effective in reducing the total numbers of viable seeds, will not destroy many others which, if conditions are suitable, are capable of producing a density of growth sufficient to smother the crop.

On the other hand, a periodic use of clean summerfallow, combined with practices that prevent the reinfestation of the soil with weed seeds, may in time reduce the numbers of viable seeds in the soil do a degree

that would constitute no serious menace to cultivated crops. Much of our agricultural land, however, is so badly infested with seeds of long period of dormancy that it would take many years, even if weeds were not allowed to produce seed, before clean crops could be grown.

The data obtained from this study indicate the relative longevity of weed seeds in soil under a tillage and cropping treatment such as generally practised in the dry prairie region of western Canada, except that plants were all destroyed to prevent re-infestation of the soil. The data do not necessarily indicate the induced or the natural periods of dormancy of seeds, but are nevertheless of practical significance for they show the behaviour of weed seeds under conditions as generally exist in cultivated land.

SUMMARY

Studies were initiated in 1937 on the relative length of dormancy, frequency of seasonal germination, vitality, and other physiological characteristics of seeds of weeds common to Western Canada. Samples of weed seeds have been taken for several years and mixed into a 2.5-inch layer of sterilized soil in the field. The soil was periodically cultivated to 3-inch depth and was kept in fallow one year and sown to spring wheat or barley in alternate years. Records of seedlings were made as they appeared.

Analyses of the data obtained show that seeds of different species differ widely in their behaviour in cultivated soil and that they could not be classified into categories showing common physiological characteristics. It was concluded that no method of attack, however effective on one weed, would be equally effective on another, for each species possesses a set of its own particular characteristics. Because of this, the results of these experiments were recorded separately for each species.

The results indicate that most species contain some seeds that germinate immediately after they are placed under favourable conditions, but that a proportion of the remaining seeds lie dormant for various periods. In some species the length of period required for all seeds to germinate, known as the *maximum* period of dormancy, is only a month or two, in others many years.

The *average* period of seed dormancy was also determined. It was found that seeds of species, even with the same maximum period of dormancy, show marked differences in the average period of dormancy. For the purpose of weed control, information on the average period of dormancy is more important, but from the point of view of weed eradication the maximum period of dormancy is of paramount importance.

Out of a total of 58 species, 6 were found to have seeds whose life span in cultivated soil does not exceed 1 year and 18 were found to have seeds whose life span usually does not exceed 3 years. With two exceptions, none of these species are particularly serious weeds. The majority of other weeds that possess periods of seed dormancy lasting many years constitute a serious agricultural problem and it is therefore concluded that the relative period of seed dormancy is one of the greatest single factors contributing to the seriousness of a weed.

Clean fallow is particularly effective on weeds with relatively short period of seed dormancy but is only partially effective or entirely inadequate on weeds with relatively long period of seed dormancy, for many seeds lying dormant during the fallow year are capable of germinating in subsequent years and in sufficient numbers to suppress the growth of crops.

With most species there is a typical seasonal periodicity of germination throughout the life span of seeds. The period of maximum or peak germination varies with the species and there is no period within the growing season when seeds of some species do not show a substantial emergence. The relationship between periodicity of germination and the relative seriousness of a weed is recorded in numerous individual cases.

The periodic recurrence of germination does not seem to be affected by soil texture nor the amount of seasonal rainfall, but is apparently determined at the outset for the great majority of the seeds.

The ratio of seeds that germinated to the total numbers of seeds added to the soil was found to vary greatly with the species. The data indicate that with most species the ratio is very low, which is due in some cases to low viability of seeds and in others to high mortality of seedlings before and immediately after emergence in the field.

The influence of date of maturity and shattering quality of seeds on the relative persistence of a weed is pointed out in many cases.

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GERMINATION OF WEED SEEDS: II. THE INFLUENCE OF TILLAGE TREATMENTS ON GERMINATION[1]

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The general farm practice in the prairie region of western Canada consists of one or two spring grain crops, which are usually wheat, alternated with one year of fallow. The purpose of the fallow is primarily to conserve moisture for the following year's crop and incidentally to reduce weed infestations. The number of cultivations on fallow range from 1 to 4, and in some cases even more if perennial weeds are to be eradicated. One cultivation is usually sufficient in preparing land for seeding.

The tillage implements that are used produce various effects on the surface soil. Some implements, such as the plow, turn the soil completely over, whereas others, such as the disc harrow, essentially cut and stir the first few inches of the surface soil. Still others, such as the blade weeder, destroy the weeds by severing their root system but leave the soil in essentially the same position as before. The different types of tillage implements might be expected to have various effects on the behaviour of weed seeds in the soil. It was therefore decided to determine the extent of germination and longevity of weed seeds under various conditions, such as are generally produced by the most common tillage practices in this region, and to determine what type of tillage practices are the most suitable from the standpoint of weed control. The study was undertaken to find the influence of the following specific factors:

(1) Depth at which weed seeds germinate most readily.
(2) Methods of cultivation in relation to germination and growth of weeds.
(3) Packing as it affects germination and vitality of weed seeds.
(4) Soil moisture in relation to delayed germination, or dormancy.
(5) Time of the year at which weed seeds germinate most readily.
(6) Mortality of weed seeds under different tillage treatments.
(7) Soil type in relation to germination and growth of weeds.

MATERIALS AND METHODS

Seeds of Russian thistle (*Salsola Pestifer*), stinkweed (*Thlaspi arvense*), wild mustard (*Sinapis arvensis*), tumbling mustard (*Sisymbrium altissimum*) and red-root pigweed (*Amaranthus retroflexus*) were chosen at random from samples grown during the current year and containing plump, well-matured

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kernels. Duplicate lots of one thousand seeds were placed in the field about November 15 in open bottom galvanized iron trays 12 inches long and 6 inches wide, containing sterilized soil to the full depth of 8 inches.

Simulated cultural treatments were carried out on 3 soil types, Haverhill loam, Hatton fine sandy loam, and Sceptre heavy clay, as follows:

(1) Seeds scattered on the surface, no tillage.

(2) Seeds mixed into the upper 2.5-inch layer of soil, no subsequent tillage.

(3) Seeds mixed into the upper 2.5-inch layer of soil, cultivated to 2.5-inch depth at intervals of about one month during the growing season.

(4) Seeds mixed into the upper 2.5-inch layer of soil, periodically cultivated as in (3) and packed after each cultivation.

(5) Seeds mixed into the upper 2.5-inch layer of soil, periodically cultivated as in (3) and water added to keep the soil continually moist.

(6) Seeds mixed into the upper 6-inch layer of soil, no subsequent tillage.

(7) Seeds mixed into the upper 6-inch layer of soil, plowed to 6-inch depth in June, cultivated periodically to 2.5-inch depth during the rest of the season.

Cultivation was simulated by a moderate amount of stirring of the soil to a 2.5-inch depth and plowing was simulated by turning the 6-inch layer of surface soil completely over. Packing was done with the use of a 4-inch diameter metal roller, with pressure applied on the roller at about 5 pounds per linear inch.

To avoid contamination, the experiment was carried out in an area surrounded by sod. The trays were covered with window screening to prevent damage from rodents and insects.

No seedlings appeared immediately after November 15, but records of seedlings emerging during the next season were made as soon as they appeared, when they were identified, counted, and pulled out with the roots.

In the fall, after the seeds had been left in the soil for one year, the content of each tray were removed and a fresh lot of similar soil and weed seeds were put in to repeat the experiment for the following year. The soils removed were washed through a 60-mesh sieve, which was fine enough to prevent the loss of even the smallest seeds, and the residues along with the seeds that survived the field treatment were placed in shallow saucers in a layer not exceeding 1 inch in depth and subjected to repeated germination tests in the laboratory with occasional stirring until no more seeds would germinate. Virtually all viable seeds germinated within a period of 3 years, although for some of the earlier experiments tests were continued for a period of 5 years.

RESULTS

By far the highest percentage emergence of seedlings of the species studied was from seeds lying on the surface of the ground (Table 1). With the exception of Russian thistle, the high emergence from this treatment

TABLE 1.—THE INFLUENCE OF TILLAGE TREATMENTS ON GERMINATION AND DORMANCY OF WEED SEEDS IN THE FIELD

Weed	Soil	Treatment *	Seasonal emergence (5-year average)		Viable seeds left in the soil after exposure during†					
			To June 30	After June 30	1936–1937	1937–1939	1939–1940	1940–1941	1941–1942	Average
			%	%	%	%	%	%	%	%
Russian thistle	Loam	1	42.6	1.3	0.3	0	0	0	0.1	0.1
		2	22.2	0.8	0.1	0	0.1	0.1	0.2	0.1
		3	21.9	0.6	0.1	0	0.1	0.25	0.2	0.1
		4	20.9	0.5	0.1	0	0.2	0.1	0.1	0.1
		5	25.3	0.1	0.1	0	0.3	0.15	0.3	0.2
		6	11.1	0.4	**	0	1.3	0.15	0.6	0.5
		7	11.7	0.4	**	0	0.7	0.15	0.1	0.2
	Sandy loam	2	18.1	0.2	0	0	0.2	0.25	0.2	0.1
		3	16.7	0.2	0.1	0	0.7	0.1	0	0.2
		4	18.1	0.1	0 1	0	0.9	0.4	0	0.3
		7	7.5	0.5	**	0	0.6	0.4	0.2	0.3
	Clay	2	35.4	0.7	1.5	0	0.5	0.2	0.2	0.5
		3	32.3	1.1	3.3	0	0.5	0.1	0.2	0.8
		4	40.3	1.3	3.9	0	0.2	0.2	0.5	0.9
		7	19.4	1.8	6.2	0	1.9	0.15	0.4	1.7
Stinkweed	Loam	1	45.5	8.7	0.2	0.2	3.7	0.5	0.6	1.0
		2	27.0	1.7	7.7	0.9	25.6	13.4	1.6	9.8
		3	27.4	8.3	3.0	0	13.1	8.1	1.8	5.2
		4	31.2	8.6	6.8	0.2	26.6	7.8	0.9	8.5
		5	33.2	8.5	5.6	0	26.9	8.6	1.4	8.5
		6	8.2	1.0	7.2	9.8	55.1	9.2	44.5	25.2
		7	18.4	5.4	**	2.2	22.6	13.5	25.0	15.8
	Sandy loam	2	27.8	1.6	**	0.7	43.5	10.5	3.8	14.6
		3	24.4	8.4	1.5	0.6	27.2	5.1	4.0	7.7
		4	28.3	8.3	4.6	0.4	20.4	6 0	4.0	7.1
		7	11.0	7.1	**	1.9	16.6	14.3	20.3	13.3
	Clay	2	30.5	3.2	15.1	9.6	46.8	32.2	14.2	23.6
		3	32.5	13.4	6.2	10.1	44.0	10.0	14.5	17.0
		4	36.6	12.0	9.3	6.7	31.1	11 9	9.9	13.8
		7	18.7	12.7	23.4	7.8	38 4	20 8	28.6	23.8
Wild mustard	Loam	1	48.6	8.8	Not included in the experiment	0	2.2	1.6	0.6	1.1
		2	39.4	2.1		3.1	5.6	20.0	8.6	9.3
		3	41.1	6.0		0.2	3.3	7 3	3.8	3.6
		4	37.1	5.7		1.6	4 8	4.6	5.6	4.2
		5	45.0	3.1		1.6	2 6	6 6	3.0	3.4
		6	14.5	1.1		9.8	3.2	30.0	23.0	16.5
		7	20.3	3.6		3.6	3.3	17.8	7.4	8.0
	Sandy loam	2	20.0	1.7		2.1	6.3	9.6	7 6	4 9
		3	22.0	4.2		1.3	3.8	6.8	7.8	4.9
		4	26.8	4.7		0.7	2.5	8.4	6.8	4.6
		7	13.9	5.2		8.5	22.8	21.6	20.4	18.3
	Clay	2	43.0	2.9		2.1	3.9	10.6	2.9	4.9
		3	48.5	6.1		1.2	3.3	5.1	1.5	2.8
		4	47.6	5.8		2.6	3.0	6.8	1.0	3.4
		7	26.1	6.0		4.0	11.4	16.4	7.6	9.8

* As indicated on page 355.
** Samples were ruined accidentally before it was possible to complete the determination.
† That is, from Oct. 31 until the following Oct. 31, except for the 1937 to 1939 period when treatment continued for 2 years.
‡ The 1936–1937 partial results are not included in the average.

TABLE 1.—THE INFLUENCE OF TILLAGE TREATMENTS ON GERMINATION AND DORMANCY OF WEED SEEDS IN THE FIELD—*Concluded*

Weed	Soil	Treatment	Seasonal emergence (5-year average)		Viable seeds left in the soil after exposure during.					
			To June 30	After June 30	1936–1937	1937–1939	1939–1940	1940–1941	1941–1942	Average
Tumbling Mustard	Loam	1	45.9	8.8	6.2	1.2	3.3	1.5	0.1	1.5‡
		2	17.6	1.8	53.4	26.8	35.1	16.6	2.9	20.4‡
		3	20.4	3.7	39.2	19.7	21.6	11.7	1.6	13.6‡
		4	15.0	3.9	26.5	20.9	22.1	8.9	0.8	13.2‡
		5	17.9	3.3	42.2	22.4	24.8	13.6	0.4	15.3‡
		6	5.6	0.6	**	24.0	44.6	20.4	20.2	27.3‡
		7	8.9	2.5	**	22.2	44.4	12.5	10.2	22.3‡
	Sandy loam	2	17.7	1.5	52.2	24.4	43.2	8.4	2.2	26.1
		3	15.0	4.8	39.8	16.3	38.6	9.1	1.9	21.1
		4	17.3	4.7	10.0	17.5	36.1	9.2	0.5	14.7
		7	6.0	2.6	57.2	18.7	46.3	21.2	12.9	31.3
	Clay	2	18.0	2.3	53.3	21.5	50.2	9.8	4.5	27.9
		3	25.7	4.8	55.8	17.6	43.5	8.1	1.5	25.3
		4	23.7	3.3	59.6	24.8	38.0	6.2	2.9	26.3
		7	8.4	2.7	46 4	42.5	70 4	47.0	18.4	44.9
Red-root Pigweed	Loam	1	18.0	12 9	1.7	0.9	3.6	0.6	0.1	1.4
		2	14.6	4.3	0.9	38 4	15.9	11.0	21.2	17.5
		3	17 1	6.1	1.2	18.6	7.4	2.6	16.0	9.2
		4	15.9	6.6	1.1	17.4	10.1	1.0	14.3	8.8
		5	18.1	2.3	1.1	19.9	4.9	3.0	7.4	7.3
		6	8.6	2.9	**	26.0	27.3	14.0	31.7	24.8
		7	9.7	5.1	3.7	15.3	14.8	3.6	14.4	10.4
	Sandy loam	2	22.0	4.9	**	15.1	11.3	2.1	17.9	11.6
		3	18.0	4.9	1.7	17.9	8.0	2.7	12.8	8.6
		4	20.2	5.8	**	11.5	6.2	2.4	14.2	8.6
		7	10.7	5.8	**	29.6	38.9	8.4	18.3	23.8
	Clay	2	17.0	12.1	22.0	33.4	10.2	12.6	29.5	21.5
		3	20.6	11 8	12.2	32.5	9.3	6.8	13.0	14.8
		4	14.3	12 9	8.2	22.5	13 1	6.9	21.5	14.4
		7	11.2	9.7	26.9	21 2	13.1	16.8	27.4	21.1

* As indicated on page 355.
** Samples were ruined accidentally before it was possible to complete the determination.
† That is, from Oct. 31 until the following Oct. 31, except for the 1937 to 1939 period when treatment continued for 2 years.
‡ The 1936–1937 partial results are not included in the average.

was associated with the least number of viable seeds that remained on the surface of the ground at the end of the growing season. In no case was the average number of viable seeds surviving this treatment greater than 3% of the total number of seeds that were scattered on the ground (Figure 1).

Except for Russian thistle, the deeper the seeds were buried, the substantially lower was the emergence of seedlings and correspondingly higher was the number of viable seeds that survived the burial period. Under conditions not disturbed by cultivation the average percentage of seasonal seedling emergence on loam soil was 49.3, 27.1 and 10.6 for seeds lying on the surface of the ground, buried at all depths in the upper 2.5 inch of surface soil, and buried all the way down to 6-inch depth, respec-

tively. The average percentage of seeds found viable at the end of the season was 1.2, 14.2 and 23.4 respectively. These results were relatively the same on stinkweed, wild mustard, tumbling mustard and red-root pigweed, all of which possess a relatively high state of dormancy of seeds.

The foregoing results did not apply to Russian thistle which possesses a relatively low degree of dormancy of seeds. Irrespective of the type of tillage treatment, fully 99% of the Russian thistle seeds, if in contact with the ground, germinated or lost their viability without germinating within a year. Many seeds germinated and produced seedlings if they were on or within an inch or two below the surface of the ground, but most of those buried deeper either germinated and failed to emerge or merely rotted away without germinating. Thus, the deeper the Russian thistle seeds were buried the lower was the percentage of seeds that emerged, but the percentage of viable seeds that survived one season's tillage treatment in the field varied but little. The average survival for the season was approximately 0.1% for treatments in which the seeds were not buried deeper than 2.5 inches, 0.2% for seeds initially buried at all depths down to 6-inch depth but some of which were later brought nearer to the surface by cultivation (treatment 7), and 0.5% for seeds that were initially buried at depths similar to those in treatment 7 but which were not subsequently disturbed by cultivation (treatment 6). Tillage which brought the seeds nearer to the surface had a tendency of lowering the number of dormant seeds, but the effect was so slight as to be regarded insignificant for all practical purposes.

Periodical cultivation of the soils, which, to begin with, contained weed seeds all the way down to the depth of tillage, increased the emergence of seedlings and hence decreased the number of viable seeds that remained in the soil at the end of the summer-fallow period. However, the increase in the emergence of seedlings was marked only after June 30 (Table 1). This was due to the fact that tillage brought up buried seeds to the surface after those originally on or near the surface had germinated, rather than to any other stimulating effect of cultivation on germination. The number of viable seeds remaining in the soil that had been cultivated at intervals during the growing season was substantially lower than in soil containing weed seeds at similar depths but which had not been disturbed by cultivation (Figure 1). Thus, the proportion of viable seeds that survived one season of fallow periodically cultivated to 2.5-inch depth and which contained weed seeds all the way down to that depth was on an average 5.2% for stinkweed, 3.6% for wild mustard, 13.6% for tumbling mustard, and 9.2% for red-root pigweed, as compared to 1.0, 1.1, 1.5, and 1.4% for cases where the soil was not cultivated and where weed seeds were left on the surface of the ground (Table 1). Where seeds were buried all the way down to 6-inch depth, instead of 2.5-inch depth, the proportion of viable seeds surviving fallow was substantially greater and amounted to 15.8% for stinkweed, 8.0% for wild mustard, 22.3% for tumbling mustard, a[illegible] 10.4% for red-root pigweed.

Some tillage treatments were repeated on loam, sandy loam, and calcareous clay soil. The results show (Table 1) a somewhat higher emergence of seedlings on clay than on the other two soils for all types of tillage treat-

ments that were employed, but the number of viable seeds surviving the different tillage treatments was essentially the same for all soils. The reason for the higher emergence of seedlings on clay was observed to be due to the existence of a finely granulated, loose surface layer. The loam and sandy loam soils generally had a firm surface crust which tended to prevent the emergence of seedlings and caused death of some before they were able to emerge.

The percentage of seasonal seedling emergence and the percentage of viable seeds surviving the cultural treatment subtracted from 100 indicates the percentage of non-viable seeds or the percentage of seeds that were viable at the time of seeding but died in the soil without emerging. The results indicate (Table 1) that the proportion of seeds belonging collectively to the two latter classes was particularly high for all weeds included in the experiment and constituted from about 30 to 92% of the total number of seeds that were added to the soil. The mortality of seeds in the soil was found to be particularly high for Russian thistle. This was because the great majority of the seeds of this weed, when buried too deeply to emerge, died and rotted away rather than remained dormant in the soil. The non-viable seeds together with those that died in the soil during the season without germinating ranged from 56 to 92% for Russian thistle and from 30 to 75% for the other weeds. The lowest mortality was for seeds scattered on the surface of the ground and the highest for seeds buried deepest in the soil.

Packing after each tillage operation in order to reduce the drying of the surface soil usually failed to show any effect on germination or on the number of viable seeds surviving the fallow period. The same results were obtained on clay, loam, and sandy loam soils (Table 1). In one case surface packing of moist loam soil after a 1 71-inch rain caused a substantial increase in the emergence of weeds. It is evident that packing dry soil is ineffective in increasing the germination of weed seeds but packing moist soil may occasionally stimulate germination.

There was no appreciable difference in the germination nor deterioration of weed seeds in soil kept continually moist by irrigation (treatment 5) as compared with soil receiving only the natural precipitation of approximately 14.5 inches (treatment 3).

As indicated in Table 2, the earliest emergence of seedlings was from seeds scattered on the surface of the ground and the latest from seeds buried deepest in the soil. The results were essentially the same on clay, loam, and sandy loam soils. The weeds emerging earliest and in greatest numbers were Russian thistle, tumbling mustard, stinkweed, wild mustard, and red-root pigweed in the order given. The great majority of the red-root pigweed seedlings emerged, even from the surface of the ground, too late to be destroyed by tillage prior to the date of seeding of spring grain crops.

The emergence of seedlings did not occur at any one time but was spread throughout most or all of the growing season, but the peak of emergence occurred at certain fixed periods, depending on the characteristic behaviour of the weed. The greatest emergence of Russian thistle occurred

TABLE 2.—INFLUENCE OF TILLAGE TREATMENTS ON EMERGENCE OF SEEDLINGS
(Totals for 3 soil types for years 1937–42, inclusive)

Weed	Treatment *	Numbers emerged during periods ending †												
		April 15	April 30	May 15	May 30	June 15	June 30	July 15	July 31	Aug 15	Aug 31	Sept 15	Sept 30	Oct 31
Russian thistle	1	6264	2562	4149	297	438	33	339	63	0	0	0	0	0
	2	595	2754	2343	250	159	91	87	79	1	0	0	0	0
	3	538	2325	2330	181	201	118	71	104	11	0	0	0	0
	4	675	2680	2627	256	172	158	84	81	11	0	0	0	0
	5	197	1047	758	131	32	31	7	1	0	0	0	0	0
	6	0	364	398	136	25	4	5	30	0	0	0	0	0
	7	0	1271	1244	421	100	60	139	67	12	1	1	0	0
Stinkweed	1	688	3918	1785	375	2403	291	1059	690	204	33	6	126	15
	2	66	2905	2070	866	1022	75	262	133	65	26	6	39	5
	3	69	2909	1704	719	1146	299	580	479	438	157	64	357	18
	4	50	3230	1901	628	1439	315	526	565	388	73	77	331	30
	5	66	3918	2010	1509	615	333	228	441	303	57	141	327	36
	6	0	450	837	252	429	72	171	33	33	12	0	6	0
	7	0	886	1324	363	535	628	772	416	373	102	37	219	8
Wild mustard	1	12	3687	2082	138	1773	480	1779	192	69	15	6	3	0
	2	40	3423	2436	265	637	73	468	25	6	14	2	2	1
	3	20	3675	2316	190	668	298	824	122	117	34	12	61	10
	4	14	3546	2501	214	677	206	737	189	70	13	2	32	3
	5	0	4218	2604	714	609	465	213	231	66	18	21	18	3
	6	0	783	1362	255	630	30	201	12	18	9	3	6	0
	7	0	1139	2668	333	293	408	809	195	67	13	1	48	4
Tumbling Mustard	1	1986	6849	1443	93	282	18	267	555	6	12	39	90	1554
	2	107	2614	1195	121	110	26	95	115	0	1	29	76	61
	3	191	3672	905	119	50	26	32	111	28	63	56	262	456
	4	124	2966	847	160	87	36	27	102	56	47	60	186	423
	5	78	3075	837	396	180	15	6	3	15	78	72	234	321
	6	0	435	846	18	27	3	63	84	0	12	3	6	3
	7	0	775	935	52	29	57	30	17	43	95	35	136	229
Red-root Pigweed	1	0	108	732	465	1626	675	2421	1188	6	81	27	3	3
	2	0	0	593	1176	1363	636	1285	623	70	49	9	11	0
	3	0	152	685	771	1700	1223	926	646	183	150	27	34	0
	4	0	0	398	1164	1428	938	1246	663	181	68	23	51	4
	5	0	0	720	1482	1068	756	141	195	60	42	84	21	0
	6	0	0	216	402	966	144	600	111	6	105	0	0	0
	7	0	00	447	457	692	746	1151	457	80	40	6	50	0

* As indicated on page 355
† No weeds emerged between Oct 31 and March 31

early in the spring, except where seeds were buried deeply in the soil, in which case emergence was delayed considerably. Hardly any germination occurred after August 15.

Substantial numbers of seedlings of other weeds, except red-root pigweed, likewise emerged in large numbers in the spring, though emergence of many seedlings continued throughout the whole of the growing season. The second peak of emergence, though not as pronounced as the first, occurred in the fall for stinkweed and tumbling mustard, both of which behave as winter annuals to some degree.

The distribution of seasonal emergence of red-root pigweed was entirely different from that of other weeds included in the experiment. The seeds did not germinate in appreciable numbers until late spring and summer. This is why the weed is particularly prevalent on land that is being fallowed, for it emerges in large numbers after many other weeds have more or less ceased to germinate, thus necessitating additional tillage to keep it down.

DISCUSSION AND CONCLUSIONS

The reduction in the number of viable seeds by one season of summer-fallow varied inversely with the depth of burial of weed seeds, the highest reduction being from seeds lying on the surface of the ground. These results indicate very forcefully (Figure 1) that tillage which tends to bury the seeds, even at shallow depths, has a definite effect of lowering the germination of seeds and of *inducing* a substantial proportion of the seeds to remain dormant in the soil for periods longer than if they were left on the surface of the ground. Perpetuation of many small seeded weeds is thus accentuated by cultivation.

The foregoing results and conclusions apply only to small weed seeds possessing a relatively high degree of dormancy, but do not apply to seeds of relatively low degree of dormancy, such as those of Russian thistle, nor possibly for relatively large seeds such as those of wild oats. The type of tillage employed appears to be of no consequence in reducing the infestations of Russian thistle seeds, because the great majority of those lying on or within an inch or two below the surface of the ground germinate as soon as conditions become suitable, but those buried deeper either germinate and fail to emerge or merely rot away without germination. The results indicate that, on an average, substantially less than 1% of Russian thistle seeds, if in contact with the ground remain viable at the end of the fallow period, irrespective at what depth the fallow is worked. Because of the relatively low dormancy of the seeds, infestations can be readily eliminated, provided no plants are allowed to produce seeds and mature plants are prevented from being carried into the treated area by the wind.

The results show that for weeds exhibiting a relatively high degree of dormancy of seeds, the number of viable seeds surviving one season of fallow that has been cultivated at intervals during the growing season is substantially lower than in soil containing the weed seeds at similar depths but which has not been disturbed by cultivation. Repeated cultivation thus partially offsets the unfavourable effects of the initial cultivation that has buried some or all of the seeds. As indicated by experimental results, however, the number of viable seeds remaining at the end of the season in cultivated soil is substantially higher than in the case where the soil is not cultivated at all and in which all weed seeds remain on the surface of the ground. This suggests that shallow tillage, such as with a suitable type of blade implement that has the least tendency of burying the seeds, should allow for greater emergence of small seeded weeds than tillage which tends to stir the soil and thus bury the seeds. In any case, tillage should be as shallow as possible, consistent with effective destruction of growing weeds.

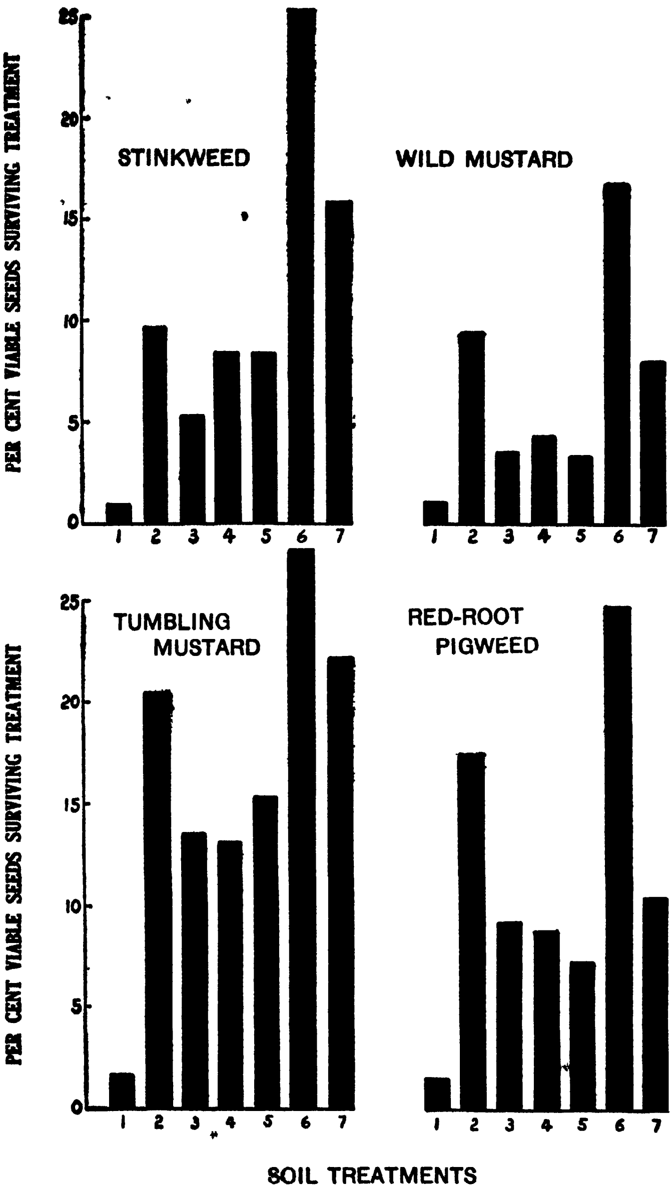

FIGURE 1.—Average percentage of viable seeds surviving one season of tillage treatment on loam soil, as follows: 1. Seeds scattered on the surface, no tillage. 2. Seeds mixed in 2 5-inch layer of soil, no tillage. 3. Seeds mixed in 2.5-inch layer of soil, cultivated 4 times to 2.5-inch depth. 4. Seeds mixed in 2 5-inch layer of soil, cultivated 4 times to 2.5-inch depth and packed. 5. Seeds mixed in 2.5-inch layer of soil, cultivated 4 times to 2 5-inch depth and watered to keep continually moist. 6. Seeds mixed in 6-inch layer of soil, no tillage. 7. Seeds mixed in 6-inch layer of soil, ploughed June 1, cultivated 3 times to 2.5-inch depth.

The results indicate that packing of fallow after each tillage operation seldom has any effect on the germination of weed seeds or on the number of viable seeds surviving the fallow period. A beneficial effect is occasionally achieved on moist soil but the results are too irregular and of insufficient benefit to warrant the adoption of this method into the regular farm practice on dryland soils.

Contrary to what was expected, there appeared to be no appreciable effect of irrigation on the germination or on the longevity of weed seeds in the soil. The longevity of weed seeds on periodically cultivated dryland soils is apparently due to their natural and induced dormancy and not to the limited supply of soil moisture. At one time or another there is sufficient rainfall during the growing season to cause the germination, or disintegration, of all seeds whose dormancy has been broken. On the other hand, an increase in precipitation over and above that required to germinate the weed seeds does not seem to affect the natural nor induced dormancy of seeds.

The results show that the earliest emergence of seedlings in the spring is from seeds lying on the surface of the ground and the latest from seeds buried deepest in the soil. This brings out another argument for shallow tillage. In order that the greatest possible number of young weeds be destroyed before a spring crop is sown, it is necessary, therefore, to have small seeds on or as near to the surface as possible. The practice of delaying the seeding of spring crops until many weed seedlings can be destroyed by tillage should be of particular benefit in combating weeds that germinate early in the spring, such as the Russian thistle. Some weeds, such as the red-root pigweed, emerge too late in the spring, even from the surface of the ground, to be destroyed by tillage prior to the most suitable date of seeding.

SUMMARY

The influence of tillage treatments on the longevity of weed seeds in the soil was found to depend in large measure on the period of induced dormancy of seeds. Weeds may be divided into two broad categories, those possessing a relatively short period of induced dormancy of seeds and those possessing a relatively long period.

For small seeds possessing a relatively long period of dormancy, the deeper the seeds were buried in the soil the substantially lower was the emergence of seedlings and correspondingly higher was the number of viable seeds that survived the burial period. The highest emergence and the lowest percentage of viable seeds remaining at the end of the growing season was from seeds lying on the surface of the ground.

For seeds possessing a relatively short period of dormancy, such as those of Russian thistle, the depth of burial was of little consequence, for those buried too deeply to emerge soon lost their viability in any case.

Periodical cultivation that brought weed seeds nearer to the surface after those originally on or near the surface have germinated, increased the emergence of seedlings and decreased the number of viable seeds in the soil. The treatment was not as effective, however, as if all weed seeds were left on the surface of undisturbed soil.

There was higher emergence of seedlings from calcareous clay soil than from loam or sandy loam, but the number of viable seeds surviving different cultural treatments was essentially the same in all soils.

Packing after each tillage operation to stimulate the germination of weed seeds was usually ineffective on dryland soils.

Irrigation, in addition to natural precipitation, had no appreciable effect on germination nor on longevity of weed seeds in the soil.

The earliest emergence of seedlings took place from seeds lying on the surface of the ground and the latest from seeds buried deepest in the soil.

ACKNOWLEDGMENT

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ACTIVITY OF PATULIN AGAINST *USTILAGO TRITICI* (PERS.) JEN.[1]

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Continuing the search for new antibiotics of microbial origin, one species of *Penicillium* isolated from mummified round-headed wood borer (*Cerambycidae*) when grown on modified Czapek-Dox liquid medium, produced a metabolism solution active against *Staphylococcus aureus* and *Escherichia coli.*

The metabolism solution produced by this mould was sent to Dr. W. D. McFarlane who isolated the active matter in crystalline form and identified it as patulin.

The name of this chemical compound "patulin" was given by Raistrick *et al.* (16) who isolated this antibiotic from a metabolism solution of *Penicillium patulum* Bainier, and who also elucidated the chemical nature of the patulin as anhydro-3-hydroxymethylene-tetrohydro-1 : 4-pyrone-2-carboxylic acid. Later it was shown by Bergel *et al.* and others (2, 5, 11, 13) that patulin was identical with the antibiotic produced by *Aspergillus clavatus* and previously designated as clavacin by Waksman *et al.* (24) and as clavatin by Bergel *et al.* (3), and also that formed by *Penicillium claviforme* to which Chain *et al.* (4) had already given the name claviformin[3]. According to recent reports it seems that patulin is a common metabolic by-product of many organisms. Thus Florey *et al.* (7) obtained it from *Aspergillus giganteus*, Karrow and Foster (12) from *Gymnoascus*, Kent and Heatley (14) from *Penicillium utricae* and *Aspergillus terreus*, Lochhead *et al.* (15) from soil *Penicillia*, Timonin and McFarlane (22) from *Byssoclamys* sp. and Anslow *et al.* (1) from *Penicillium expansum.*

The activity *in vitro* of patulin, claviformin, clavacin and clavatin against Gram positive and Gram negative bacteria has been reported by the above mentioned authors. Furthermore, several workers (1, 9, 17, 23) also reported on the antifungal activity of patulin *in vitro.* In this laboratory, when patulin was made available in crystalline form and its activity against bacteria and certain fungi was established, the investigation on the activity of patulin against loose smut of wheat was outlined with the object of obtaining information on the possibility of practical control of loose smut of wheat with the aid of patulin.

EXPERIMENTAL

The *Penicillium* sp. when grown on modified Czapek-Dox (glucose 40 gm.; $MgSO_4 . 7H_2O$ 0.25 gm.; $NaNO_3$ 3 gm.; KH_2PO_4 0.5 gm.; $ZnSO_4 . 7H_2O$ 0.006 gm.; $FeSO_4 . 7H_2O$ 0.006 gm.) Raulin-Thom and peptone glucose (peptone 10 gm.; commercial glucose "grape sugar" 40 gm.) liquid media in stationary or submerged cultures produced a metabolism solution as indicated in Table 1 with considerable activity. The assay for

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[3] There is at present lack of agreement as to the correct designation of this antibiotic. In this paper the term "patulin" is used since that was the name under which the crystalline material was furnished by Dr. McFarlane.

TABLE 1.—INFLUENCE OF MEDIUM ON PRODUCTION OF ANTIBIOTIC

Medium	Culture	Zone of inhibition, mm./diam.	
		Staph. aureus	*E. coli*
Czapek-Dox + glucose (40 gm./l.) Med I	Surface Submerged	35 30	32 30
Czepek-Dox + honey (50 gm./l) Med. II	Surface Submerged	40 37	40 38
Czapek-Dox + comm. glucose (40 gm./l.) Med. III	Surface Submerged	32 28	30 29
Med. I + peptone (10 gm./l.)	Surface Submerged	25 0	26 0
Med. II + peptone (10 gm./l.)	Surface Submerged	28 0	29 0
Med. III + peptone (10 gm./l.)	Surface Submerged	30 0	29 0
Med. I + potato extract (25 ml./l.)	Surface Submerged	40 37	39 36
Med. II + potato extract (25 ml./l.)	Surface Submerged	41 38	42 40
Med. III + potato extract (25 ml./l.)	Surface Submerged	36 32	37 34
Raulin-Thom	Surface Submerged	31 32	30 30
Peptone 10 gm.; commer. glucose (40 gm./l.)	Surface Submerged	28 0	29 0

potency of these metabolism solutions was carried out by the standard cup method as outlined by Schmidt and Moyer (19). The maximum activity of metabolism solutions in stationary cultures was obtained on the 8th to 10th day of incubation whereas in submerged cultures it developed on the 6th and 7th day of incubation at 27–28° C.

From the data presented in Table 1 it is evident that addition of peptone (10 gm./l.) to the media in surface cultures caused the reduction in potency of the metabolism solution and complete inhibition of production of antibiotic in submerged cultures. On the other hand addition of 25 ml./l. of potato extract to the modified Czapek-Dox medium resulted not only in the increase in potency of the metabolism solution but also enhanced the germination of the spores and growth of mycelium. Thus the cultures with potato extract produced surface mycelial pellicle in less than 24 hours, whereas cultures without potato extract required 48 to 56 hours' incubation to produce the same type of pellicle. The best yield of crystalline patulin, 1.325 gm./l., was obtained from the cultures containing potato extract. The potato extract was prepared according to the method outlined by Robbins *et al.* (18).

Activity of Crystalline Patulin

Patulin produced by this organism was active against Gram positive and Gram negative bacteria. Thus it inhibited the growth of *Staph. aureus* H. in 1 : 125,000 and *Escherichia coli* in 1 : 160,000 dilution. However, the addition of 5% fresh horse serum reduced this activity by about $\frac{2}{3}$ of the original, and the activity was completely destroyed when serial dilutions, prepared in nutrient broth, were autoclaved for 15 min. at 15 lb. pressure, (21, 22).

The activity of patulin has been also assayed against several fungi. The data presented in Table 2 indicate that patulin in 1 : 20,000 dilution, reduced the rate of growth of several fungi, namely, *Ascochyta pinodes*,

Table 2.—Fungistatic activity of patulin *in vitro*

	Dilution of patulin (1000)						
	20	40	50	66	80	100	Control
Ascochyta pinodes	++	++	+++	++++	++++	++++	+++
Ascochyta pinodella	++++	++++	++++	++++	++++	++++	++++
Ascochyta pisi	++	+++	++	++++	++++	++++	++++
Fusarium culmorum	++++	++++	++++	++++	++++	++++	++++
Helminthosporium sativum	+++	++++	++++	++++	++++	++++	++++
Rhizoctonia solani	++++	++++	++++	++++	++++	++++	++++
Ustilago Tritici	–	–	–	–	–	–	++++
Blastomyces Gilchristi	+++	+++	+++	+++	+++	+++	++++
Epidermophyton flocossum	+	++	++	+++	++++	++++	++++
Microsporum lanosum	++	++	+++	++++	++++	++++	++++
Trichophyton crateriforme	++	+++	+++	+++	++++	++++	++++
Trichophyton gypseum	++	+++	++++	++++	++++	++++	++++
Trichophyton purpureum	+++	+++	++++	++++	++++	++++	++++

– No growth.
\+ Very poor growth.
++ Poor growth.
+++ Good growth.
++++ Normal growth.

A. pisi, Epidermophyton flocossum, Microscporum lanosum, Trichophyton crateriforme, T. gypseum, and completely inhibited the growth of *Ustilago Tritici.*

Originally the spores (chlamydospores*) of *Ustilago Tritici* were received from the Dominion Rust Research Laboratory, Winnipeg, Manitoba, and were marked as "Strain I". This strain was used by the Cereal Division, Central Experimental Farm, Ottawa, for a study of the resistance of wheat hybrids to loose smut and the material (smutted plants) used in this work was obtained from the Cereal Division.

Activity of Patulin against *Ustilago tritici*

The activity of patulin was assayed against this fungus in mycelial stage, by the dilution method and the following results were obtained:

Fungistatic — 1 : 400,000
Fungicidal — 1 : 100,000

* The chlamydospores of *Ustilago Tritici* in this paper will be referred to as spores.

The fungicidal activity was determined by transferring the original bit of inoculum after 5 to 10 days' incubation on fresh patulin-free medium and the limiting dilution for complete inhibition of growth was recorded as fungicidal activity.

The activity of patulin was also determined against the spore stage. Results summarized in Table 3 indicate that complete inhibition of germination of spores was obtained in 1 : 66,000 dilution and partial inhibition (56% spores germinated) in 1 : 200,000 dilution. These results were obtained by the following method: spores of the fungus, obtained from the smutted wheat heads, were suspended in the serial patulin dilution and 1 ml. of suspension of each serial dilution was poured on the surface of potato dextrose (2%) agar in Petri dishes. By rotating the plates the spores were distributed over the agar surface. The plates were then incubated at 20° C. for 24 and 48 hours and with the aid of a microscope the germinated and dead spores were counted in each microscope field of vision. Thus the spores in 25 microscope fields were counted and the percentage of germinated spores for each dilution calculated. The results are summarized in Table 3.

TABLE 3.—ACTIVITY OF PATULIN AGAINST SPORES OF *Ustilago Tritici*

Concentration of patulin	Germinated spores	
	24 hrs. incub.	48 hrs. incub.
	%	%
1 : 4,000	0	0
1 : 8,000	0	0
1 : 10,000	0	0
1 : 20,000	0	0
1 : 40,000	0	0
1 : 50,000	0	0
1 : 66,000	0	0
1 : 80,000	0	7.7
1 : 100,000	7.6	11.2
1 : 133,000	28.5	29.5
1 : 200,000	45.4	55.8
Control	51.9	85.8

During examination of the plates it was noticed that plates poured with spore suspensions containing patulin in 1 : 100,000 dilution and lower were free from bacterial contamination, whereas control plates and plates with patulin in dilutions higher than 1 : 100,000 were badly contaminated. After 48 hours' incubation the counting of spores on control plates was very difficult. Thus the use of patulin in isolation of loose smut of wheat in pure culture may be recommended.

The effect of pretreatment in patulin solution on the viability of the spores was also investigated. In order to obtain information, in this case, the spores were suspended in serial patulin dilutions and allowed to stand at room temperature for 2, 4, 8, 12 and 24 hours. The samples were then centrifuged, supernatant liquid decanted, spores resuspended in sterile

tap water and suspensions were again centrifuged. To insure complete removal of patulin from the spores this process was repeated twice. One ml. of patulin-free spore suspension was then poured on the surface of solidified agar in Petri dishes and after 24 and 48 hours' incubation the germinated and dead spores, with the aid of the microscope, were counted. Control samples were passed through the same procedure only in sterile tap water.

Results summarized in Table 4 indicate that the percentage of germinated spores is in reverse correlation with the concentration of patulin and length of time of pretreatment. The highest dilution which completely inhibited the germination of spores after 24 hours' pretreatment was 1 : 20,000.

TABLE 4.—GERMINATION OF SPORES AS INFLUENCED BY TIME OF PRETREATMENT AND CONCENTRATION OF PATULIN SOLUTION

Concentration of patulin solution	Counted after 24 hrs. incub.					Counted after 48 hrs. incub.				
	Time of treatment—hours					Time of treatment—hours				
	2	4	8	12	24	2	4	8	12	24
	Percentage of germinated spores									
1 : 4,000	0	0	0	0	0	0	0	0	0	0
1 : 8,000	10 50	8 50	0 10	0.04	0.0	18 35	10 13	2.45	0 06	0.0
1 : 20,000	22 00	15 35	0 78	0 38	0 0	24 75	10 23	1 02	0 65	0.0
1 : 40,000	35 18	18 12	1 56	0.98	0 93	38 39	23.45	4 36	3.53	2.73
1 : 50,000	47 35	31 34	6 58	2 93	1 34	56.45	38 03	9.53	7 35	2.86
1 : 66,000	69 12	38.43	29 38	19.75	15.43	72.76	45 45	31 32	31 42	20.40
1 : 80,000	72 45	48 24	37.13	21 15	19 01	70 31	51 34	46 51	28 32	24.80
1 : 100,000	73 34	65.85	43 75	30.45	23 25	74 42	68 34	56.34	36 15	27.93
Control (water)	72 84	74 35	75 26	72.83	73 46	75.36	72 86	86.43	84 15	84.44

EFFECT OF PATULIN ON GERMINATION OF WHEAT SEED

In view of the possibility of utilization of patulin in practical control of loose smut of wheat, the effect of patulin on the germination of wheat seed was investigated. Wheat seeds, healthy in appearance and not

TABLE 5.—EFFECT OF PATULIN ON GERMINATION OF WHEAT SEED

Concentration of patulin solution	Planted while wet			Planted after drying		
	Germination			Germination		
	Strong	Weak	Total	Strong	Weak	Total
	%	%	%	%	%	%
1 : 4,000	42	4	46	37	8	45
1 : 8,000	77	7	84	71	10	81
1 : 20,000	90	5	95	86	7	93
Water (control)	93	5	98	91	6	97
Control untreated				93	6	99
Control untreated				93	4	97

TABLE 6.—INFLUENCE OF TREATMENT ON THE WEIGHT OF WHEAT SEED

Time soaking, hours	Tap water			Patulin—1 : 20,000 solution		
	Wt. of dry seed	Wt. of wet seed	Increase	Wt. of dry seed	Wt. of wet seed	Increase
	gm.	gm.	%	gm.	gm.	%
2	6.90	7.90	14.49	6.95	7.95	14.39
4	6.80	8.16	20.00	6 85	8.10	18.25
8	7.00	8.80	25.71	7 00	8 75	25 00
12	7.10	9.30	30.99	7.05	9.20	30.50
24	6.96	10.16	45.98	6.90	9.70	40.58
Average of total	6.95	8.86	28.03	6 95	8.74	25.74

TABLE 7.—GERMINATION OF WHEAT SEED AS INFLUENCED BY LENGTH OF TIME OF TREATMENT

Treatment in hours	Water		Patulin—1 : 20,000 solution	
	Germination		Germination	
	Planted dry	Planted wet	Planted dry	Planted wet
	%	%	%	%
2	96	97	95	98
4	100	99	98	99
8	96	99	95	96
12	96	96	94	95
24	98	98	93	94
Total	486	489	472	483
Average	97.20	97.80	94.40	96 60
Control untreated	98		97	
Average	97.5			

injured by threshing, were subjected to the following treatment. Four samples of seed, 200 seeds each, were soaked for 24 hours in 1 : 4,000, 1 : 8,000, 1 : 20,000 and in tap water respectively. After treatment each sample was divided into 2 lots (100 seeds each) and one lot was sown in flats in greenhouse soil immediately after soaking, while the second lot prior to sowing was allowed to dry at room temperature to the original weight.

From the results obtained (Table 5) it is evident that patulin in concentrations used is toxic to the wheat embryo. Thus 1 : 4.000 dilution reduced germination by 53.60 and 53.06%, 1 : 8,000 by 16.50 and 14.29% and 1 : 20,000 by 4.12 and 3.98% of dry and wet planting respectively, when the germination of control samples (water soak) is expressed as 100%.

From results obtained it is evident that patulin in 1 : 20,000 dilution only slightly reduces the germination of wheat seed and this dilution was used in further experiments.

To study the effect of length of time of soaking on the germination of wheat seed the samples of wheat, 200 seeds in each treatment, were soaked in 1 : 20,000 dilution for 2, 4, 8, 12 and 24 hours. Control samples were kept in tap water for a corresponding length of time. In order to obtain rates of adsorption of patulin solution and water for different periods of time of soaking the samples were weighed before and after treatment. After treatment and before weighing the surface of the seeds was dried on blotting paper. The results of this experiment summarized in Tables 6 and 7 indicate that the rate of absorption of patulin solution was lower than absorption of the water. The difference, after 24 hours soaking amounted to 5.4%. The percentage of germinated seeds in patulin treated lots was also lower, amounting after 24 hours soaking to 5.71 and 4.08% of dry and wet seed planting respectively.

Effect of Patulin on Loose Smut *in situ*

In order to obtain some information on the effect of patulin on the loose smut *in situ*, artificially infected wheat seeds, obtained from Cereal Division, Ottawa, were soaked in patulin solution (1 : 20,000) for 24 hours and controls soaked in tap water for the same length of time. After treatment the samples were again divided into 2 lots and 1 lot was sown immediately after treatment in greenhouse soil, in 7-inch pots, 10 seeds to the pot, while the second lot prior to sowing was dried to the original weight. Control without treatment was also included.

Plants were grown in the greenhouse and watered with tap water. The emergence of seedlings for each treatment was recorded and later, at heading time, the smutted plants were counted and the percentage of infection calculated. Results of this experiment are summarized in Table 7. From the data presented it is apparent that the emergence in patulin treated samples was 4.09 and 3.06% lower than in control treatment of dry and wet seed planting respectively. This reduction again illustrates the phytocidal effect of patulin on the wheat embryo. Furthermore, the results also clearly indicate that patulin 1 : 20,000 dilution does not control loose smut *in situ*.

This experiment was repeated with different seed material and a new set of data was obtained but the trend of infection remained the same.

It is of interest to note that the fungicidal activity of patulin *in vitro* against mycelium and spores as determined is 1 : 100,000 and 1 : 20,000 (1 : 60,000) respectively and the reduction in germination of patulin treated seeds indicate that patulin solution was able to diffuse through the seed coat. In spite of these facts the pathogen *in situ* was not controlled by patulin. In explanation of this, two possibilities could be suggested (1) that patulin was inactivated by the organo-chemical complex of the wheat kernel, and (2) that the resting stage of mycelium imbedded in the scutellum is resistant to patulin.

According to Cavallito *et al.* (6) and Geiger and Conn (8) chemical compounds containing the sulfhydryl group inactivate patulin *in vitro*. In this respect grain does contain a considerable amount of proteins the chemical formulae of which contain the sulfhydryl group. To investigate the possibility that patulin was inactivated by the content of the wheat

kernel, whole flour was prepared from the parent grain of the hybrid seed and different amounts of it were added to 50 ml. of 1 : 20,000 patulin solution. The suspensions after 24 hours' standing at room temperature were filtered through filter paper, the soluble proteins coagulated by heat (10 min. in boiling water bath) and filtered off. The activity of patulin was then assayed against *Staph. aureus*. It was found (Table 9) that an addition of 10 gm. of flour to 50 ml. of patulin solution reduced the activity by $\frac{4}{5}$ of the control, which was passed through the same procedure, except for the addition of flour. The results, therefore, indicate that part of the patulin was inactivated by the content of the wheat kernel. Plant pathologists, on the other hand, have demonstrated (20) that the hyphae of the pathogen in the majority of cases are imbedded in the scutellum of the wheat kernel, and if the chemical composition of the scutellum and the embryo are considered a third explanation may be suggested.

According to Hinton (10) the wheat kernel on an average, contains 1.5%, by weight, of scutellum and 1.2% of embryo. Furthermore he stated that number one Manitoba contained 9.3 and 168 γ/gm. vitamin B_1 and 15.4 and 30.3% fat lipoids in embryo and scutellum respectively. Taking his data as a basis for calculation, 200 wheat kernels weighing 6.9gm. would contain 0.77 and 17.39γ of vitamin B_1 and 0.0128 and 0.0314 gm. of fat lipoids in embryo and scutellum respectively. The addition of 1.9γ/ml. of vitamin B_1 to the assay medium resulted in complete inhibition of the activity of patulin and furthermore, it was found that patulin is not

TABLE 8.—EFFECT OF PATULIN ON *Ustilago tritici in situ*

Treatment	Emergence	Total plants harvested	Smutted plants	Infected
	%			%
Control (untreated)	96	93	23	24.73
Water (planted wet)	98	95	19	20 00
Water (planted dry)	98	91	19	20.08
Patulin* (planted wet)	95	92	21	22 83
Patulin* (planted dry)	94	91	23	25 27

* Patulin = 1 : 20,000 solution.

TABLE 9.—ACTIVITY OF PATULIN AGAINST *Staph. aureus* AS INFLUENCED BY WHEAT FLOUR

Weights of flour added per 50 ml. (1 : 20,000) patulin solution	Limiting dilutions showing complete inhibition of growth
gm.	
10.0	1 : 25,000
5.0	1 : 66,000 ±
2.5	1 : 66,000
1.0	1 : 100,000
0.0 (control)	1 : 125,000

soluble in wheat germ oil. Therefore it may be suggested that the scutellum due to the high content of vitamin B_1 and fat lipoids, protects the imbedded mycelium from the activity of the patulin.

On the other hand the chemical composition and degree of resistance of the mycelium imbedded in scutellum to patulin is not known at present. However, taking the results presented in Table 8 into consideration and comparing them with results published by Zalkssky (25) the reduction in percentage of infection due to the water treatment suggests that the mycelium some time during the 24 hours' soaking passed from the dormant stage into the active one, and owing to lack of oxygen a certain percentage of mycelium died as shown in this paper (reduction in percentage of infection), and was completely eliminated under anaerobic conditions as in Zalkssky's experiments. If, therefore, during the 24-hour treatment the mycelium was in the active stage additional support is given to the theory of protection of mycelium by scutellum; because the active mycelium *in vitro* is very susceptible to patulin.

SUMMARY

The effect of the composition of the medium on yield of patulin by *Penicillium* sp. in surface and submerged cultures has been described and the fungistatic and fungicidal activity of patulin *in vitro* against mycelium and spores (chlamydospores) of *Ustilago Tritici* (Pers) Rostr. has been determined. The phytocidal effect of patulin on the wheat embryo was elucidated and the activity of patulin against the loose smut of wheat *in situ* was also investigated. Furthermore, the inactivity of patulin in wheat kernel was discussed and the theory to explain the inactivity of patulin in the scutellum of wheat kernel was outlined.

It was found that addition of 25 ml./l of potato extract to the modified Czapek-Dox medium stimulated the germination of the conidia of *Penicillium* and enhanced the formation of surface pellicle, thus shortening the time of incubation for maximum production of antibiotic. The best yield of crystalline patulin was also obtained from this medium which amounted to 1.35 gm. per litre of metabolism solution. On the other hand addition of peptone to modified Czapek-Dox medium reduced the yield of patulin in surface cultures and completely inhibited the formation of antibiotic in submerged cultures.

The 1 : 20,000 dilution of patulin reduced the growth *in vitro* of *Ascochyta pinodes*, *A. pisi*, *Epidermophyton flocossum*, *Microsporum lanosum*, *Trichophyton crateriforme*, *T. gypseum* and completely suppressed the growth of *Ustilago Tritici* in 1 : 100,000 dilution.

The fungistatic and fungicidal activity of patulin against mycelium of loose smut of wheat was found to be 1 : 400,000 and 1 : 100,000 respectively. The spores (chlamydospores) of this fungus proved to be more resistant than mycelium and the highest dilution which completely inhibited the germination of spores in the direct contact with the antibiotic proved to be 1 : 66,000 dilution and 1 : 20,000 dilution was required in the pretreatment of the spores for 24 hours to achieve the same results.

The patulin was found to be a phytocidal to the wheat embryo. Thus when seeds were soaked for 24 hours in 1 : 4,000, 1 : 8,000 and 1 : 20,000 patulin dilutions and were planted in greenhouse soil immediately after

treatment, the germination was reduced by 53.06, 14.39 and 3.06% respectively, if the percentage of germinated seeds in controls (soaked in tap water) was taken as a 100% germination. The number of germinated seeds was further reduced if the seeds, after the treatment, were allowed to dry at room temperature to the original weight. In this case the reduction of germination amounted to 53.61, 16.58 and 4.12% respectively.

Patulin proved to be ineffective against the pathogen *in situ.* Thus when artificially infected seeds were soaked for 24 hours in 1 : 20,000 patulin solution the percentage of infected plants was not reduced as compared with untreated seed material.

The addition of 10 gm. of whole wheat flour to 50 ml. of 1 : 20,000 patulin solution reduced the activity of the solution by four-fifths of the original, and addition of vitamin B_1, 1.9 γ/ml. completely inactivated it. Furthermore, it was found that patulin is not soluble in wheat germ oil.

It was suggested that due to the high concentration of vitamin B_1 and fat lipoids in the scutellum it acts as a protective body for the mycelium of the pathogen imbedded in it.

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A NOTE ON SPRING FROST INJURY TO CEREAL CROPS[1]

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Spring frost of unprecedented proportions was encountered at Winnipeg during the period from May 10 to 15. It was unprecedented both in severity and duration. The following is the temperature record at The University of Manitoba.

Date	*Minimum temperature* °F.
May 10	23
May 11	*13*
May 12	16
May 13	24
May 14	32
May 15	17

The superficial damage to wheat, barley and oats according to observations made May 12 was somewhat as follows:

Montcalm barley. All plants completely collapsed to soil level.

Mindum wheat. Damage obviously less than in the case of barley. While the barley leaves were wilted and white throughout their area, those of wheat, although frozen back to the soil level, were green some distance back from their tips, and about 8% of the plants showed little or no damage.

Renown wheat. Situtation similar to that in Mindum wheat, although more of the leaf showed complete collapse and no plants were undamaged.

Vanguard oats. Damage decidedly greater than in case of Renown wheat. Plants were not quite as far advanced as those of the other three crops. They were 2 to 4 inches tall (stretched) while those of wheat and barley were 3 to 5 inches. Renown wheat was sown April 12 and 13; Vanguard oats April 24. Mindum wheat and Montcalm barley were sown April 19.

The Mindum wheat and Montcalm barley were on adjoining fields. Renown wheat and Vanguard oats were on fields about one-and-one-half miles distant, and adjoined each other.

In order to obtain quantitative measurements of damage some detailed data were taken beginning May 12. The plan was to determine:

1. The recovery on the basis of plant counts taken immediately after the frost, and repeated at an interval or intervals of several days.

2. A laboratory study of individual plants to determine to what extent, if any, "growing points" or tiller buds might be uninjured behind the line of frost damage.

Recovery as Measured by Plant Counts

Counts were made in 4 1-rod sections of drill rows in each of the four crops on May 12 and again on May 22. The data are presented in Table 1.

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TABLE 1.—AVERAGE OF PLANT COUNTS IN 4-ROD ROWS OF EACH OF 4 CROPS IMMEDIATELY AFTER SEVERE FROST, AND AT AN INTERVAL OF 10 DAYS

Crop	May 15	May 22		Reduction in stand
		Live plants	Dead plants found	
				%
Montcalm barley	116	89	7	23
Mindum wheat	78	67	3	14
Renown wheat	259	219	7	15
Vanguard oats	123	98	12	20

According to these data barley and oats made distinctly less recovery than Mindum wheat or Renown wheat. The recovery of barley and oats was essentially the same, and that of the 2 wheats essentially the same. The recovery may be said to have been reasonably good in all cases since the greatest damage left 77% of the original stand. The yield from such stand will probably not be significantly reduced.

On May 22 Mindum and Renown wheat had the appearance of a full stand. Mindum showed a healthy green colour. The discoloration of the original damaged leaves was practically completely obscured by the younger leaves that had completely overgrown them. In the Renown wheat some discoloration was still in evidence.

Montcalm barley also had the superficial appearance of a full stand. It presented a pale green aspect because the original whitened damaged leaves were still in evidence among the newer green ones.

Vanguard oats gave the impression of a somewhat reduced stand although it appeared good.

The leaves of barley and wheat were now 6 to 8 inches long when stretched. Those of oats were 4 to 6 inches.

LABORATORY STUDY OF PLANTS

Representative plants were taken up and brought to the laboratory on May 15. These were carefully examined under hand lenses and low power binoculars to determine;

(a) How far back frost damage extended.

(b) Whether there was a live "shoot" within the enveloping damaged leaves or leaf sheaths behind the damage line.

(c) Whether live tiller shoots or tiller buds could be found.

The following statements describe the typical situation on the basis of examination of 15 to 25 plants from each crop:

Mindum and Renown wheat. In nearly all cases the culm, or a core of inner leaves enveloping the culm was found undamaged at some distance behind the line of obvious damage. One or two tillers starting just above the kernel and varying in length from $\frac{1}{16}$ to one inch long were found invariably. The most common length was less than $\frac{1}{2}$ inch.

Montcalm barley. The situation was similar to that in the case of wheat. In most cases the line of obvious damage was further toward the base of the plant, being somewhat below the soil level.

FIG. 1. Frost damaged barley plants dissected to show uninjured internal and basal "shoots". At left: central culm. At right: central culm and two tillers (about two thirds natural size).

Fig. 1 shows two typical barley plants. On the one at the left the short undamaged culm is shown, the outer envelope of leaves and leaf sheaths having been dissected away. The plant at the right shows the main culm and two tillers.

Vanguard oats. In most cases an undamaged central core was found some distance back from the line of damage. In a few plants— about one-fifth of those examined—the tip of this central core had been damaged by frost. Tillers or distinctly discernible tiller buds were not found in any of the plants.

DROUGHT COMPLICATION

The damage situation may have been influenced more or less by drought. No rain fell during a period from prior to sowing up to the time of the final observations. The moisture situation at the time of sowing was satisfactory. Observations made on June 1 showed that there had been no further consequential reduction in stand in Mindum or Renown wheat. A very decided reduction in the stand of Montcalm barley was due very largely if not entirely to cutworms. The oat plot, where the earlier observations had been made, had been plowed up and resown because it appeared to be suffering from drought. Since it may be assumed that rain would have promoted recovery, and good recovery was made in spite of the absence of rain, it may be concluded that wheat, oats and barley, at least the varieties involved in this study, will withstand 19 degrees of frost, when the plants are in the stage represented by those in this study, namely 3 to 5 inches tall with 2 to 4 leaves unfolded.

TESTING SEED FOR SMUT SPORES AS AN AID IN CONTROLLING CEREAL SMUTS IN SASKATCHEWAN[1]

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The use of the centrifuge method for examining cereal seed for the presence of smut spores, as a means of deciding whether or not the seed needs to be treated for the control of smut, is receiving increasing attention throughout the Prairie Provinces at the present time. However, the idea has already been subjected to a considerable amount of investigation and trial in the Province of Saskatchewan. As early as 1935, Simmonds and Mead (8) suggested that the centrifuge method could be used to determine whether or not a given sample of wheat seed needed treatment for bunt. More recently, Russell and Ledingham (6) and Mead *et al.* (4) tested a large number of cereal seed samples produced in Saskatchewan. These samples were given comprehensive tests for the presence of physical abnormalities and pathogenic organisms, including smut spores. In the first of these two papers, the authors reported the results of field experiments with wheat seed which had been tested for smut and they suggested that the centrifuge test should be used before deciding whether or not to treat for smut. In both papers, the data presented showed that cereal seed produced in this province is relatively free from appreciable amounts of smut and other pathogenic fungi. Greaney and Machacek (2), after examining cereal seed from all over Canada, stated that, "The cleanest wheat seed examined in 1939 was from Saskatchewan."

Since it has been found that much of the cereal seed produced in Saskatchewan is free from smut, the farmers in this area have been advised to have their seed tested for the presence of smut spores before deciding whether or not to treat it. However, this laboratory was neither staffed nor equipped to give this service to the farmers on a large scale. Therefore, in response to the need, a commercial laboratory in Saskatoon commenced testing cereal seed for smut, using the method developed in our laboratory. It has now been in operation for 6 years and, during that time, has tested thousands of samples of seed wheat and hundreds of samples of oats and barley. During the past 4 years, a large number of samples from this commercial laboratory have been sown in field plots to find out how the amount of smut on the seed compared with the amount of infection in the resultant crop grown under normal field conditions. Also, the records of the laboratory have been synopsized to show what percentages of the samples tested fell into the different smut classes, and how the incidence of the smut diseases compared in the different soil zones of the province. This paper embodies the results of these investigations.

MATERIALS AND METHODS

Samples of wheat, oats, and barley were sown in field plots at Saskatoon for 4 years in succession. In the last year, duplicate plots of oats and barley were sown at Indian Head. For seed, an equal number of samples

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was taken at random from each smut class of each cereal. These varied from samples which were entirely free from smut spores to those which carried a heavy spore load. The amount of smut on the seed, indicated by the various smut classes, is explained by Russell and Ledingham (6, p. 673). A few rows were sown with artificially smutted seed each year for the purpose of comparison.

Sufficient seed was picked by hand from each sample to sow 5 8-foot rows with 100 seeds each. This hand-picking, although a laborious process, got rid of a lot of weed seeds, trash, and poor seed and insured much better germination. The seed was sown in regular order, starting with the cleanest samples and working up to the most heavily smutted, in order to avoid contaminating the cleaner samples during seeding. The rows were sown 6 inches apart as in ordinary field practice. The wheat in these tests was sown relatively early; i.e., about the first of May, but the barley and oats were sown about the twentieth of May, because numerous tests conducted here and elsewhere have shown that bunt is favoured by cool soil temperatures, while on the other hand the covered smuts of oats and barley are favoured by warmer temperatures at seeding time. No soil temperature data were taken at seed level but at a depth of 6 inches the average difference in mean temperature for the 10-year period, 1927 to 1937, at Saskatoon on May 1 and May 21 was 5° C. According to records supplied by the Physics Department of the University of Saskatchewan, the average mean temperature of the air for a 44-year period at Saskatoon on these two dates varied by 5° C.

At harvest time, the heads of smut in the barley and oats were counted in the field because they could be seen easily and this method reduced the amount of labour involved. As bunt of wheat is sometimes hard to detect, especially if only a few kernels in a head are affected, the rows of wheat were cut and tied in small sheaves, and later they were taken to the laboratory and threshed. This was accomplished by scrubbing the heads with a metal block, covered with wire screening, as they lay on a sheet of screening ($\frac{1}{4}$-inch mesh) over white cardboard. By this method, even a single bunt ball in a head could be detected readily. During the first 3 years, only the smutted heads were counted but in the fourth year the healthy heads were counted also, in order that the exact percentages of infection could be computed.

At the beginning of the tests, the loose smuts of wheat and barley were not taken into consideration because it was known that they could not be controlled by treating the seed with formaldehyde or fungicidal dusts. After it was found that the false loose smut of barley was present in this area, the heads of loose smut occurring in the rows of barley were recorded separately and an investigation of the loose smuts of barley was begun. However, the figures given in Table 1 for barley smut refer only to covered smut, caused by *Ustilago Hordei* (Pers.) Lagerh.

In these experiments, in the first 2 years, the 3 "trace" classes were not kept separate and are all listed under "trace." Later, however, it was realized that it was important to separate these classes in order to ascertain which classes carried enough smut to justify seed treatment. Accordingly, they were not only kept separate during the last 2 years of the test, but twice as many samples were sown as in each of the other 4 classes.

EXPERIMENTAL RESULTS

The data secured from the 4 tests are summarized in Table 1. The results obtained were what one would expect except that there were, in some cases, great variations in the amount of smut produced by different seed samples in the same smut class. Little or no smut appeared in the

TABLE 1.—THE AVERAGE PERCENTAGE OF SMUTTED HEADS DEVELOPED FROM SEED OF EACH SMUT CLASS, SHOWING THE RELATION BETWEEN SPORE LOAD AND SUBSEQUENT INFECTION UNDER ORDINARY FIELD CONDITIONS

Year	Cereal	Total number of samples	Percentages of smut occurring in the various classes						
			Clean	Trace−	Trace	Trace+	Slight	Moderate	Heavy
			%	%	%	%	%	%	%
1942	Wheat	20	0	—	0.10	—	0.17	0	0.77
	Oats	20	0	—	0.33	—	1.60	5.17	7.50
	Barley	20	0	—	0.10	—	0.17	1.47	1.87
1943	Wheat	50	0	—	0.16	—	0.95	0.80	1.60
	Oats	50	0	—	0	—	0	0	0.24
	Barley	50	0	—	0	—	0	0	0.03
1944	Wheat	100	0.05	0.01	0.22	0.56	1.17	1.16	1.67
	Oats	100	0.01	0.04	0.05	0.17	0.36	0 69	2.85
	Barley	100	0.01	0.04	0.05	0.06	0.08	0.19	0.23
1945	Wheat	100	0	0.03	0.17	0.33	0.96	0.80	2.00
	Oats	200	0.14	0.09	0.07	0.65	1.05	5.15	8.85
	Barley	200	0.01	0.05	0.09	0.10	0.55	1.22	3.75

rows from seed graded as clean and, on the whole, there was a significant increase in the amount of infection from seed of the successively higher smut classes. In the case of wheat, even the heavily naturally smutted seed never produced as much bunt as artificially inoculated seed sown in the same tests. There were some instances in which the plants of a class had less smut than those of the class below it. As examples of this, the wheat in the "moderate" class produced less bunt every year than the wheat in the "slight" class. Also, in any one class there were, in some cases, great variations in the amount of smut produced by different samples. In all classes, there were usually a number of samples which produced no smut whatsoever. These were more numerous in the lower classes and

TABLE 2.—THE NUMBER OF SAMPLES IN EACH CLASS WHICH FAILED TO PRODUCE ANY SMUT. THE FIGURES ARE BASED ON THE FIELD TESTS OF 1944 AND 1945

Cereal	Smut classes													
	Clean		Trace−		Trace		Trace†		Slight		Moderate		Heavy	
	1944	1945	1944	1945	1944	1945	1944	1945	1944	1945	1944	1945	1944	1945
Wheat	9	10	18	17	10	15	6	14	4	3	1	2	1	1
Oats	9	8	18	12	15	13	10	6	1	1	3	0	0	0
Barley	9	9	16	12	17	13	14	11	7	2	5	1	2	0

Note:—20 samples were used in each of the trace classes and 10 samples in each of the other classes.

fewer in the higher ones, as is shown in Table 2. In the more heavily smutted classes, oats sometimes produced a considerably higher percentage of smutted heads than did wheat or barley.

These results, shown in Table 1, suggest that, in ordinary farm practice, the samples in the classes with a "trace" or less of smut on the seed could have been sown without treatment, as in no case was the average infection for these classes over one-quarter of 1%. However, more experimental data are needed to determine this point. Certain individual samples in these lower classes showed as high as 1.2% infection in the case of wheat, 1.4% in the case of oats, and 0.7% in the case of barley, but very few of the samples had infections approaching these amounts. On the other hand, certain samples bearing a "trace plus" or more of smut produced considerable smut in the subsequent crop, indicating that seed grain bearing a "trace plus" or more should be treated.

ANALYSIS OF SEED-TESTING RECORDS

Six years' records of the commercial laboratory's tests have been studied and the data relating to smut have been summarized. The two main objects of the study were to learn what proportions of the cereal seed fell in the different smut classes from year to year, and how the incidence of the covered smuts varied in the three main soil zones of Saskatchewan.

The data showing the distribution of seed samples over the smut classes are given in Table 3. For the first 3 years, the 3 "trace" classes

TABLE 3.—THE PERCENTAGES OF WHEAT, OATS, AND BARLEY FALLING IN THE VARIOUS SMUT CLASSES FROM 1939 TO 1944, INCLUSIVE

Cereal	Crop year	Smut classes						
		Clean	Trace−	Trace	Trace+	Slight	Moderate	Heavy
		%	%	%	%	%	%	%
Wheat	1939	74.1	—	25.2	—	0.7	0.0	0.0
	1940	85.1	—	13.4	—	0.7	0.5	0.3
	1941	84.9	—	13.4	—	0.6	0.8	0.3
	1942	76.1	10.0	7.9	2.7	2.1	0.9	0.4
	1943	79.6	8.5	6.3	2.1	2.0	1.3	0.2
	1944	83.1	5.1	6.6	2.2	1.9	0.8	0.1
	Mean	80.5	7.9	6.9	2.3	1.3	0.7	0.2
Oats	1939	35.6	—	52.5	—	7.8	2.9	1.2
	1940	31.2	—	38.3	—	16.7	9.3	4.5
	1941	26.4	—	43.4	—	14.6	8.1	7.5
	1942	13.0	25.6	15.1	9.8	17.2	11.9	7.4
	1943	27.5	17.3	19.5	15.0	10.7	7.1	2.8
	1944	39.5	11.5	14.2	18.8	10.7	4.2	1.1
	Mean	28.9	18.1	16.3	14.5	12.9	7.2	4.1
Barley	1939	22.2	—	55.5	—	6.1	16.2	0.0
	1940	17.7	—	39.8	—	16.8	17.7	8.0
	1941	16.5	—	49.5	—	13.7	13.7	6.6
	1942	7.8	16.2	23.6	21.8	14.0	9.6	7.0
	1943	17.9	19.5	20.8	17.8	13.9	6.8	3.3
	1944	23.7	10.3	13.7	24.4	17.1	5.5	5.5
	Mean	17.6	15.3	19.4	21.3	12.6	11.6	5.1

were not kept separate, but during the last 3 years this was done. A number of points brought out by these data may be emphasized. In the first place, a large percentage of the wheat samples are free or practically free from bunt spores. If it is considered that all wheat samples found to be free of bunt do not require treatment, then the average percentage of the samples, tested from the years 1939 to 1944, inclusive, which did not require treatment was 80.5%. In the case of oats and barley, a smaller percentage of the seed samples were free from smut. The figure for oats, corresponding to the figure given above for wheat, was 28.9% and for barley it was 17.6%. This represents a very substantial portion of the wheat seed and a considerable portion of the oat and barley seed of Saskatchewan. In the relatively wet season of 1942, the covered smuts of oats and barley were unusually plentiful. This is reflected in the low percentage of these cereals in the "clean" class that year. Although there appear to be distinct seasonal variations in the smut spore load on the seed samples tested, there is no clear-cut indication of either an increase or a decrease in the prevalence of the covered smuts throughout the period from 1939 to 1944.

The influence of regional differences should be taken into consideration when studying the smut problem as a whole. This effect can be seen even in a single province (See Table 4). Most of the land which has been brought under cultivation in Saskatchewan lies in the first 3 soil zones as set forth by Mitchell *et al.* (5). These are referred to as the Brown, Dark

TABLE 4.—VARIATIONS IN THE PERCENTAGES OF SAMPLES REQUIRING TREATMENT IN THE DIFFERENT SOIL ZONES

Cereal	Year	Number of samples tested			Percentage needing treatment[1]		
		Brown	Dark brown	Black	Brown	Dark brown	Black
Wheat	1942	557	773	492	13.1	3.8	1.6
	1943	593	883	711	14.7	3.4	1.0
	1944	847	1461	1095	10.8	4.2	1.5
	Mean	—	—	—	12.9	3.8	1.4
Oats	1942	59	198	210	37.3	45.4	50.5
	1943	85	213	249	16.5	36.1	40.1
	1944	73	260	295	12.3	37.6	38.9
	Mean	—	—	—	22.0	39.7	43.2
Barley	1942	36	83	104	50.0	50.6	55.8
	1943	49	132	116	22.4	48.4	43.1
	1944	59	99	95	28.8	59.6	60.1
	Mean	—	—	—	33.7	52.9	53.0

[1] Samples showing a "trace plus" or more of smut.

Brown, and the Black soil zones respectively because of the prevailing colour of the surface soil. The climate and vegetation vary somewhat from zone to zone, and these factors have, over a long period of time, left their imprint on the soils found therein. The records of the commercial

laboratory were analysed and the percentages of the samples of each cereal, for the 3 soil zones comprising most of the cultivated areas of the province, were listed under their appropriate smut classes. In Table 4 is shown for each zone the percentage of samples which required treatment for smut. Figures for the first 3 years are not given because the "trace" classes were not kept separate in those years.

It is evident from the data presented in Table 4 that there is a distinct difference in the prevalence of the cereal smuts in the different zones. Bunt of wheat is most prevalent in the Brown zone and least prevalent in the Black, while the reverse appears to be true of the covered smuts of oats and barley. However, the conclusions concerning the smuts of barley and oats are based on much fewer samples than those respecting bunt of wheat.

DISCUSSION

Any distinct change in common agricultural methods is apt to be accompanied by a period of uncertainty and adjustment. When it was first suggested that the farmers of this province should depart from the old practice of treating their seed grain regularly each year and treat it in future only when tests indicated that treatment would be beneficial, many farmers and other agricultural men were slow to accept the proposal. They wanted to be shown that the tests were reliable and the results satisfactory.

The investigations dealt with in this paper were designed to secure information as to the practicability of the new method of attacking the smut problem. It was felt that the method should be tested under field conditions over a period of years. This has been done. The evidence accumulated during the 4 years that these field tests have beer. conducted, shows that the new method is reliable and practicable as far as the covered smuts of wheat, oats, and barley are concerned. The value of the method depends upon a number of factors as indicated below.

In the first place this method will prove most useful in areas, such as Saskatchewan, where a large proportion of the seed grain is relatively free from smut and other seed-borne parasites. In regions where the proportion of seed samples which need treatment is high, there is not the same incentive to have the seed tested because the chances are great that it will require treatment. Also in regions where wheat is sown in the autumn and exposed to infection in the soil, testing the seed for smut will not serve the same purpose. In the case of wheat in Saskatchewan, for the past 6 years, over 80% of the seed tested by the commercial laboratory was free from bunt spores and, presumably, fit to sow without treating. This would represent a big saving in labour and material to the farmers of this province if the new practice were adopted on a large scale. In the case of oats and barley, a larger proportion of the seed required treatment but a considerable proportion of the seed of these cereals could have been sown to advantage without treatment. While the material used in these experiments may not have been fully representative of all the cereal seed used in those years in Saskatchewan, the number of samples was fairly large and fairly well distributed over the Province (See Table 4).

To some, it may seem surprising that different samples of seed, bearing approximately the same load of smut spores, should vary so much in the amount of smut produced under the same environmental conditions in the field. However, as far as oats and barley are concerned, Zade (10), Gage (1), and Tapke (9) have shown that the mycelial inoculum established under the hulls is of more importance in determining the amount of infection in the subsequent crop than is the amount of ungerminated spores clinging to the outside of the hulls. But it is the latter form of inoculum that is detected by the centrifuge test, so that it cannot be expected that equal infections will always develop from different seed samples from the same smut class. It seems probable that the samples which bore considerable smut spores but produced no smut when sown in the field had little or no smut mycelium established beneath the seed hulls.

According to the authors just mentioned, the extent to which smut mycelium develops beneath the hulls of the coarse grains depends upon a number of factors operative from flowering time through to and including the storage period. Moisture is one of the main factors favouring the development of the mycelium. In Saskatchewan conditions are, on the average, more moist in the Black soil zone than in the Brown soil zone, and therefore more favourable to the development of this type of smut inoculum. It seems quite probable that this is the main reason why the covered smuts of oats and barley are more prevalent in the Black soil zone.

It has been suggested that the same amount of smut spores on cereal seed might produce heavier infections of smut if the seed were sown in certain other parts of Saskatchewan. For example, it is possible that higher percentages of bunt would develop in the Brown soil zone and higher percentages of the covered smuts of oats and barley would develop in the Black soil zone than were obtained at Saskatoon, which lies in the Dark Brown soil zone. However, in 1945 the barley and oat plots were duplicated at Indian Head, which lies in the Black soil zone, and the infections in that case were lower than those obtained at Saskatoon. More experimental data is needed to settle this point.

It should be recognized that other considerations may render it advisable to apply treatment to seed grain even when smut is absent. The presence of other seed-borne diseases, such as seedling blight caused by *Helminthosporium sativum* P. K. & B., in some cases may make treatment desirable. Although *H. sativum* causes a discoloration of wheat and barley seed, known as smudge, and severely damages seedlings developing from affected kernels, it is seldom present on more than 1% of the kernels on the average in this province (4, 6, 7). Also, seed-coat damage from threshing and handling when the grain is dry and brittle may call for seed treatment as a protection against the saprophytic as well as parasitic organisms of the soil (4, 6). On the other hand, extensive experiments with sound seed, reported by Greaney and Machacek (2, 3), and experiments conducted at this laboratory with plump wheat seed having a low percentage of embryo exposure (4, 6), have shown that seed treatment in such cases gives little or no improvement in yield. So that, unless there is an actual need for seed treatment, it may be merely a waste of time and money to apply it. In fact, treatment with formaldehyde is a detriment rather than a help, in some cases, because it reduces the germinative vigour of the seed.

Whenever possible, it is desirable to have cereal seed tested by an approved method for the presence of seed-borne diseases. The prime objective of seed-testing, from the pathological standpoint, is not to discourage the application of seed treatment but to ascertain which samples will benefit from it and which samples do not require it. The objective may be considered two-fold, to emphasize its desirability in those cases where it is needed and to prevent economic waste where it is apt to do no good. If conducted on a large scale, this practice should lead to a more thorough and efficient control of cereal diseases. In order to be completely satisfactory, seed testing should determine the germinative vigour of the sample, the condition with regard to seed-borne parasites, and the condition with regard to mechanical injury of the seed coat. The records of such tests, if conducted on a large scale over a period of years, would yield valuable information as to the prevalence and distribution of such diseases throughout the region from which the samples were obtained.

One aspect of the problem, which should be kept in mind, is the attitude of the farmers to this new way of keeping the cereal smuts under control. In the majority of cases, the ones who have tried it seem to be very well satisfied with it. The results have served to give them confidence in the recommendations which they have received concerning the samples they have submitted for testing. When their seed does not require treatment, this information gives them great satisfaction, and when treatment is advised they are not likely to neglect the operation.

There is little doubt that the new method of securing control of the cereal smuts is workable in Saskatchewan as far as bunt of wheat is concerned; but in the case of barley and oats, there may be more room for argument. To begin with, less study and investigation have been devoted to the seed of the coarse grains in this province; and it has been shown that a smaller proportion of the samples examined were free of smut spores. Also, it may be found that seed-borne parasites other than smuts are more prevalent and important in the coarse grains than they are in wheat. The presence of false loose smut of barley (*Ustilago nigra* Tapke) complicates the problem, as far as making recommendations is concerned. On account of the loose nature of the spore masses, most of the spores are blown away before the grain is threshed and fewer spores are left to be detected by the centrifuge test, and yet a considerable amount of inoculum in the form of mycelium may be established in the parenchyma of the hulls and in the epidermis of the pericarp, as described by Gage (1) and Zade (10) in the case of the loose smut of oats. In such cases, seed treatment should be recommended, because the fungicides used in the control of covered smut (*Ustilago Hordei* (Pers.) Lagerh.) will effectively destroy this fungus too, but owing to the early dissipation of the spores the test may not indicate that an appreciable amount of inoculum is present. Further investigation is needed to clarify the question.

SUMMARY

A new method of dealing with the covered smuts of cereals has been developed in Saskatchewan. The seed samples are examined by the centrifuge method, and only those samples which carry an appreciable amount of smut spores are treated.

The method has been in operation on a fairly large scale for 6 years. It has given good results and appears to be regarded favourably by the farmers who have tried it. Its reliability has been checked by growing a large number of tested samples in experimental field plots.

Field experiments indicate that it is safe in this province to sow without fungicidal treatment seed grain which shows no more than a trace of smut, providing that it is free from other important seed-borne parasites and that it is of good quality, but more experimental data is needed to determine the proper limits of tolerance.

There is a considerable variation in the amount of smut which will develop, under the same growing conditions, in the crop from different samples carrying equal spore loads of smut. In other words, the amount of smut which will develop under the same environmental conditions appears to depend on the variety of the host, the physiologic form of the fungus, and other factors, as well as upon the amount of inoculum present. In the case of oats and barley, the chief factor may be the extent to which the mycelium of the parasite has become established under the hulls of the grain.

An analysis of 6 years' records of seed testing showed that approximately 80% of the wheat, 30% of the oats, and 20% of the barley which was tested was free from smut spores and therefore did not require treatment for smut.

There appears to be a distinct correlation between the soil zone and the prevalence of the cereal smuts in Saskatchewan. Bunt of wheat was most prevalent in the Brown soil zone and least prevalent in the Black, while the reverse was true of the covered smuts of oats and barley.

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DRIED WHEY AS A SUBSTITUTE FOR DRIED BUTTERMILK IN CHICK RATIONS[1]

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Dried buttermilk and dried skimmilk were, some years ago, among the main sources of riboflavin in poultry rations. During the war years, as these products became increasingly difficult to obtain, it was timely that part of the great volume of liquid whey, available from the increased production of cheese and casein, should be conserved in the form of dried whey to aid in offsetting this deficiency.

Most of the work reported on the use of dried whey has been in connection with its value in production and hatching rations. Davis, Norris and Heuser (5) reported that hatchability in poultry was favourably influenced by the inclusion of dried whey in the ration. They attributed the beneficial effect of the dried whey to its riboflavin content rather than its protein content. In addition, Christiansen, Halpin and Hart (2), in hatchability studies, showed by results obtained from groups receiving synthetic riboflavin, that the factor supplied by dried whey was riboflavin. Bearse (1) found that a breeder's ration, fed with scratch grain, gave an equal increase in hatchability when supplemented with 5% powdered whey, 3 pounds of condensed buttermilk per 100 birds per day or 3% condensed buttermilk containing cereal grasses.

Culton and Bird (4) conducted experiments with chicks, studying growth and "curled-toe paralysis" as affected by supplying varying amounts of riboflavin as crystalline riboflavin, dried skimmilk and dried whey. They concluded that the growth promoting effect of dried whey could be explained on the basis of its riboflavin content, but that dried skimmilk exerts a greater growth promoting effect than can be explained on this basis. Christiansen *et al* (2) tested dried whey as a substitute for soybean oil meal in chick rations and concluded that the protein of whey (milk albumin) was without value as a supplement, and that the supplementary value of whey was due to its vitamin content. Jukes (10) and Sullivan *et al* (12, 13) showed, on the other hand, that the growth response from whey powder could not be accounted for by its riboflavin content alone.

Hammond and Titus (8) reported that dried whey was adequate in chick rations as a source of the members of the vitamin B-G complex ordinarily supplied by dried skimmilk. Dried whey substituted for dried skimmilk in a poor quality ration consisting chiefly of ground oats and dried skimmilk, gave superior results. Hill and co-workers (9) suggested that improvement in the growth of chicks resulting from the addition of 10% dried distillers' solubles or 5% dried brewer's yeast or 4% dried whey to either of two practical chick rations was not due to riboflavin or protein but to an unidentified growth factor or factors.

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From the work which has been reported it would appear therefore, that, although the main value of dried whey in poultry feeding lies in its vitamin content and more especially its riboflavin content, there is a possibility that other factors play a part in its promotion of growth.

EXPERIMENTAL

In order to determine the suitability of dried whey as a substitute for part or all of the dried buttermilk in rations for growing chicks, eleven groups, each of 35 Barred Plymouth Rock cockerel chicks, were fed on rations containing from 0 to 20% of dried whey[1] replacing successively larger amounts of dried buttermilk.

The newly hatched chicks were banded and placed in electrically heated brooders in an air conditioned room kept at a thermostatically controlled temperature of 80° F. At the end of 4 weeks the chicks were sufficiently well feathered to allow the use of the electric heaters to be discontinued, and at the end of 5 weeks the condition of the birds warranted their being placed in growing batteries where no artificial heat was supplied.

Feed and water were before the birds at all times and the total consumption of feed for the 10-week period per group was recorded. One per cent each of oyster shell, bone meal and grit were mixed in the ration for the first 6 weeks after which time these ingredients were omitted from the ration and supplied *ad libitum*.

Birds which died during the first week of the experiment were replaced with birds from the same hatch which had been maintained on a normal chick starter ration. Deaths occurring during the initial week were not considered as being attributable to the ration. The mortality during the subsequent 9 weeks was recorded.

The birds were weighed individually at the end of the second week and at the end of each subsequent week until they were 10 weeks of age, at which time the experiment was terminated.

Dried whey was used to replace dried buttermilk in the rations on the basis that it contained approximately one-half as much riboflavin as found in dried buttermilk. This assumption was based on the results of analysis conducted in this laboratory on a large number of commercial samples during recent years together with the results of other workers. Calculation of the riboflavin content of each of the experimental rations showed that there was an adequate amount, at least, of riboflavin in all of the rations regardless of the combination of dried whey and dried buttermilk. Using the lowest assay figures ever obtained in these laboratories, Evans, Young and Branion (6, 7), for the various types of feedstuffs incorporated in the ration, the minimum riboflavin levels of the rations ranged from 1450 to 1800 micrograms per pound. Calculations of the maximum levels, using the highest assay figures on record in these laboratories, showed a range of riboflavin values of 2600 to 3500 micrograms per pound. Since it is extremely unlikely that all of the ration components were of minimum riboflavin potency, there is little doubt that all of the rations met the

[1] The dried whey was obtained from the Milverton Creamery, Milverton, Ontario. It was stated to contain no filler.

recommended allowance for riboflavin of about 1600 micrograms per pound (Norris (11), Titus (14) and Committee on Animal Nutrition, National Research Council, Washington (3)).

The protein level was maintained in all rations at approximately 18%. To this end, it was necessary to increase the amount of meat meal slightly at the expense of the ground barley as increasing amounts of dried whey were used. Analyses showed that the dried whey contained 12.5% crude protein whereas the dried buttermilk contained 31.6%.

The rations used in the experiment are shown in Table 1.

TABLE 1.—COMPOSITION OF RATIONS

Ingredients	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11
Ground oat groats	21	21	21	21	21	21	21	21	21	21	21
Ground wheat	21	21	21	21	21	21	21	21	21	21	21
Ground yellow corn	21	21	21	21	21	21	21	21	21	21	21
Cereal grass	1	1	1	1	1	1	1	1	1	1	1
Dehydrated alfalfa[1]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Salt (iodized and manganized)[2]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cod liver oil (fortified Nopco XX)[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Ground barley	14.50	12.75	11.75	10.25	8.75	7.25	5.75	4.50	2.75	1.25	0.00
Dried buttermilk	9	8	7	6	5	4	3	2	1	0	0
Dried whey	0	2	4	6	8	10	12	14	16	18	20
Meat meal[4]	9.5	10.0	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	13.5
Per cent crude protein[5]	18.3	18.3	18.1	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.1

[1] A mixture of 3 commercial varieties of dehydrated alfalfa.
[2] This salt contained 0.02% KI and 2.0% $MnSO_4.4H_2O$.
[3] The cod liver oil contained 3000 I.U. Vitamin A and 400 A.O.A.C. units Vitamin D per gram.
[4] A mixture of 3 commercial varieties of meat meal.
[5] Calculated from results of analyses carried out in the Department of Animal Nutrition laboratories.

RESULTS AND DISCUSSION

The average weekly weights and survival data are shown in Table 2 and the average weekly weights and gains are presented graphically in Figure 1.

The data were compared by the use of the following formulae:

$$(1)\ \text{Variance} = \frac{nS\,(x^2) - (Sx)^2}{n\,(n-1)}$$

where n = number of birds per group
x = final weight of each single bird at the end of the 10-week period.

(2) Standard error of the Difference between Means

$$= \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

where s_1^2, s_2^2 and n_1 and n_2 are the variances and the number of chicks respectively for the two groups under comparison.

TABLE 2.—AVERAGE WEEKLY WEIGHTS (GMS.) AND SURVIVAL DATA

	Group	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks
No dried whey	1	84.6	132.8	202.2	282.2	382.1	510.0	642.5	831.1	1002.3
9% dried buttermilk		35*	35	35	35	35	35	35	35	35
2% dried whey	2	93.2	151.7	226.7	332.3	447.5	583.6	773.7	921.5	1079.7
8% dried buttermilk		35	35	35	35	35	34	33	32	32
4% dried whey	3	92.5	149.3	228.1	330.2	448.8	576.9	734.0	897.4	1055.4
7% dried buttermilk		35	35	35	35	35	35	35	35	35
6% dried whey	4	91.0	143.7	217.1	317.2	432.3	567.2	722.6	877.7	1025.6
6% dried buttermilk		35	35	35	35	35	35	35	35	35
8% dried whey	5	88.5	142.5	219.7	319.8	433.6	574.7	718.8	898.0	1069.5
5% dried buttermilk		35	35	35	35	35	35	35	35	35
10% dried whey	6	89.9	142.6	212.6	304.8	415.1	524.3	666.0	809.7	967.2
4% dried buttermilk		34	34	34	34	34	34	34	34	34
12% dried whey	7	93.9	145.2	218.1	310.7	424.9	558.7	696.1	856.8	1018.8
3% dried buttermilk		35	35	35	35	35	35	35	35	35
14% dried whey	8	84.2	133.9	199.1	283.2	388.4	512.1	643.6	817.8	982.9
2% dried buttermilk		35	35	35	35	35	35	35	34	35
10% dried whey	9	83.6	131.5	195.9	283.2	387.4	519.3	661.5	820.5	941.5
1% dried buttermilk		34	34	34	34	34	34	33	33	33
18% dried whey	10	96.6	150.2	226.1	321.9	432.6	568.7	711.5	867.5	993.3
No dried buttermilk		35	35	35	34	34	34	34	34	34
20% dried whey	11	86.6	136.0	202.3	286.9	387.7	511.3	621.1	782.5	888.7
No dried buttermilk		35	35	35	35	35	35	35	35	35

* Number of survivors.

TABLE 3.—SIGNIFICANCE OF DIFFERENCE BETWEEN RATIONS

Group number	Significantly better than	Significantly poorer than
1	11	2
2	1, 6, 8, 9, 10, 11	None
3	6, 9, 11	None
4	9, 11	None
5	6, 9, 11	None
6	11	2, 3, 5
7	11	None
8	11	2
9	None	2, 3, 4, 5
10	11	2
11	None	1, 2, 3, 4, 5, 6, 7, 8, 10

For any group to show a mean weekly weight significantly different from that of another group with a degree of certainty of 95% or greater, the difference between these means must exceed twice the standard error of this difference.

On the basis of the individual weights at 10 weeks, each group was compared with every other group. The results of these comparisons are shown in Table 3.

TABLE 4.—TOTAL FEED CONSUMPTION BY GROUPS FOR THE 10-WEEK PERIOD

Group No.	Feed (lb.)	Group No.	Feed (lb.)	Group No.	Feed (lb.)
1	293	5	290	9	297
2	293	6	295	10	293
3	290	7	296	11	294
4	295	8	294		

The feed consumption of each group is given in Table 4. It will be seen that this was fairly constant for all groups and the differences in growth were apparently not related to differences in the amount of feed consumed.

During the initial period of the experiment all groups receiving more than 12% of dried whey showed marked symptoms of oedema. In practically all birds of these groups, general swelling of a watery nature was apparent, indicating increased subcutaneous fluid. The condition appeared during the first week and persisted for 3 to 4 weeks. After this time the external symptoms gradually disappeared. Detailed water consumption records were not kept during the course of the experiment but it was noted that as the amount of dried whey in the ration increased, the water consumption increased. The oedema may have been caused by the large amount of lactose present in the whey. By increasing their water intake the birds may have been able to dilute the excess lactose and to gradually stimulate their excretory system in such a way as to get rid of the excess lactose and at least overcome the external symptoms of the oedematous condition. It will be noted from the survival data (Table 2) that the oedema caused very little, if any, mortality. The growth data in Figure 1 and Table 2, also indicate that the early growth of all groups as judged by weight with the possible exception of that group receiving 20% dried whey, was quite satisfactory, suggesting that, during the period when the symptoms of oedema were evident, no serious loss or retardation of growth occurred. The growth of the 20% group (Group No. 11) was much poorer than that of any other group during the fourth week and this may have been due to the oedema. In the case of the other groups on the high levels of whey, it is possible that a retardation of growth may have occurred but that it was masked by the increase in body water content. In so far as the authors are aware, no other investigators have fed higher levels than 10% of dried whey in chick rations.

From these data it appears that dried whey can be used satisfactorily, in amounts up to 8 or 10%, to replace dried buttermilk in chick rations when the necessary adjustments for riboflavin and protein are made. It should be pointed out, in view of the variation in the commercial processing of dried whey, that these levels may only apply to this particular type of whey. With other types it is possible that either somewhat lower or higher levels would be found to be suitable. In amounts greater than these levels, even up to 18%, growth was still fairly satisfactory, but in view of the development of oedema, it is considered that these higher levels are not advisable. About 2% dried whey appears to give optimum growth while 20%, representing a complete replacement of the dried buttermilk, resulted in definite retardation of growth.

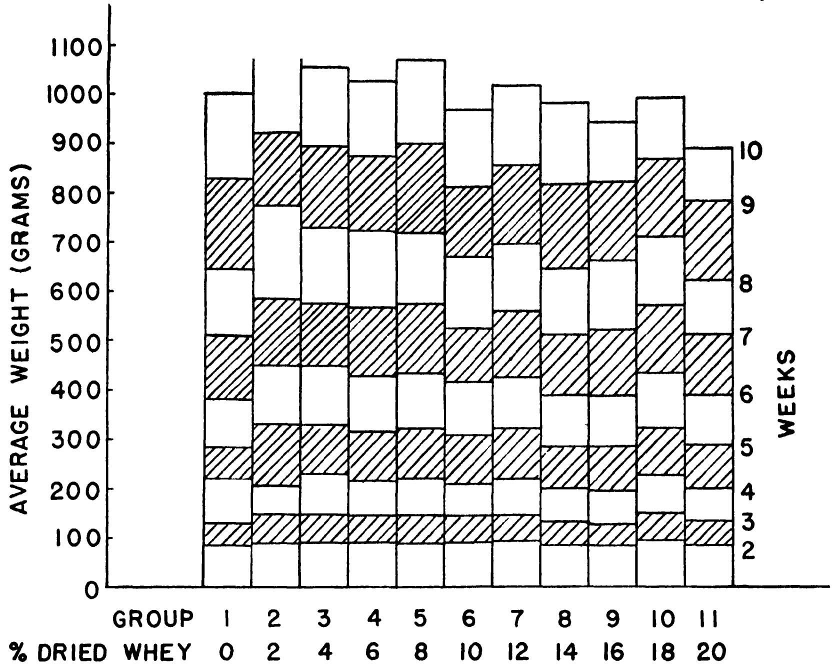

FIGURE 1. Average weekly gains and weights on rations with various amounts of dried whey substituted for dried buttermilk.

The present experiment suggests that dried buttermilk may possess some essential growth factor or factors not present in dried whey. Similarly there also is an indication that dried whey may contain some factor or factors not present in the dried buttermilk. From a consideration of the trend of the results for those groups receiving the "low buttermilk" diets, it would appear that some dried buttermilk, possibly 2 to 3%, may be essential for optimum growth. It also appears, in considering group 1 in relation to the groups receiving the mixture of dried buttermilk and dried whey that some dried whey produces better growth than rations containing dried buttermilk alone.

CONCLUSIONS

Dried whey, in amounts up to 8 or 10%, was used satisfactorily in rations for growing chicks to replace part of the dried buttermilk when the necessary adjustments were made in the riboflavin and protein levels of the ration.

Higher levels of dried whey, 12 to 20%, resulted in the onset of an oedematous condition, although growth, as judged by weight and mortality, was little, if any, affected. This condition was accompanied by an increased water consumption and the external symptoms gradually disappeared.

Although the quantity of dried buttermilk necessary for good growth appears to be small, there is some indication in this work that it should not be completely replaced by dried whey. There is also a suggestion that dried whey may contain some essential growth factor or factors not present in dried buttermilk.

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ALFALFA SEED PRODUCTION IN NORTHERN SASKATCHEWAN AS AFFECTED BY BEES, WITH A REPORT ON MEANS OF INCREASING THE POPULATIONS OF NATIVE BEES[1]

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CONTENTS

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INTRODUCTION

In the province of Saskatchewan the principal area growing alfalfa seed is located on the grey soils in the northern districts of settlement. The first alfalfa seed produced in this area was grown about 1930 near the village of White Fox, about 90 miles east of Prince Albert, and this district still is one of the main centres of production. Farmers soon recognized the value of the new crop and the acreage increased rapidly. The estimated production for the Province reached a peak of 5,500,000 pounds in 1941 and the estimated average for the 6 years 1939-44 is 2,400,000 pounds. This seed consists almost entirely of the Grimm variety of *Medicago media* L. Pioneer growers, with small fields surrounded by bush, reported exceptionally heavy yields, up to as high as 1000 pounds per acre and commonly 200 to 500 pounds per acre. However, with the clearing and cultivation of wooded land and a corresponding increase in the size of field, seed yields tended to drop sharply, until at the present time the average yield is about 75 pounds with 200 to 300 being uncommon. Consequently, in later years, the maintenance of seed production has depended largely upon the newer fields, especially those situated in districts recently opened for settlement.

The yields of alfalfa seed are influenced by many factors. Among these, weather conditions, plant disease, and both beneficial and harmful insects are of prime importance. The value of bees as pollinators in the White Fox area, with methods of protecting them, has been reported summarily by Salt (65). Extensive investigations have been carried out by Knowles (37), mainly upon the relations of climate and bees to tripping. The investigations outlined in the present paper form not only a continuation of their work but also a more intensive study of the bee populations and of the means of maintaining them.

LIST OF BEES TAKEN AT WHITE FOX, WITH TAXONOMIC NOTES

Early in this study it became apparent that bees varied both generically and specifically in their ability to trip alfalfa blossoms and that the principal genera concerned were *Megachile* and *Bombus*, while *Osmia*, *Coelioxys*, *Psithyrus* and *Anthophora* were of value. Bees belonging to the genera *Halictus* (*s.l.*) and *Andrena* have been reported as trippers in southern Ontario by Engelbert (18) but no members of either of these genera were seed tripping alfalfa in northern Saskatchewan. As far as possible, the individual species were studied, fairly extensive collections being made and identified. The list of species which follows includes all the bees collected on various flowers in the White Fox area. Although some species were not collected on alfalfa, the list is made complete to facilitate later reference in this paper and to aid in distribution studies.

Megachilidae

Osmia dacotensis Mitch.
Megachile (Anthemois) relativa Cress.
Megachile (Anthemois) nivalis Friese
Megachile (Anthemois) inermis Prov.
Megachile (Delomegachile) gemula Cress.
Megachile (Delomegachile) gemula var. *fulvogemula* Mitch.
Megachile (Delomegachile) melanophaea Sm.

Megachile (Delomegachile) frigida Sm. (= *vidua* Sm.)
Megachile (Xanthosarus) latimanus Say
Megachile (Sayapis) pugnata Say
Coelioxys lucrosa Cress.
Coelioxys moesta Cress.
Coelioxys dubitata Sm. (= *rufitarsis* Sm.)

Bombidae
Bombus rufocinctus Cress.
Bombus rufocinctus var. *iridis* Ckll. and Porter
Bombus rufocinctus var. *prunellae* Ckll.
Bombus rufocinctus var. *albertensis* Ckll.
Bombus borealis Kby.
Bombus californicus Sm.
Bombus terricola Kby.
Bombus ternarius Say
Bombus ternarius var. *expallidus* Ckll.
Bombus huntii Greene
Bombus perplexus Cress.
Bombus vagans Sm.
Bombus vagans subsp. *bolsteri* Franklin
Psithyrus ashtoni Cress.
Psithyrus suckleyi Greene
Psithyrus insularis Sm.

Anthophoridae
Anthophora furcata Pz.

Apidae
Apis mellifera L.

Although subspecies and varieties are included in the above list as a matter of record, in all subsequent discussion such subdivisions are grouped under the species name.

It has been suggested by Mitchell (46) that *nivalis* may possibly be a race of *relativa* or a species closely related to *relativa*. The males of the two forms appear similar, although the males of *Megachile* normally show specific differences in the genitalia and concealed sternites (48-50). The females differ in the colour of the scopa (entirely pale in *relativa;* apically black in *nivalis*), in the pubescence of the sixth tergite (tomentose and golden in *relativa;* fuscous in *nivalis*), and in the greater average size of *nivalis*. Females in the subgenus *Delomegachile* are sometimes subject to variation of the scopal colour within specific limits (50).

Material in the Canadian National Collection amply supports these views. However, the females bear on the sixth tergite some suberect hairs; in *relativa* these are small, pale and evenly distributed but in *nivalis* they are large, black and widely separated, occurring laterally. At White Fox 10 males were reared from the same log as 7 *nivalis* females, one pair being from the same tunnel. These males were compared with 10 males, believed to be *relativa* and obtained from scattered localities in eastern Canada, where *nivalis* is rare; no stable differences were found, although in each case the genitalia and hidden sternites were examined.

The distribution of the two forms is of interest in deciding their taxonomic status. Field collecting at White Fox, which is well within the Canadian Zone, showed *relativa* to be somewhat more abundant than *nivalis;* 35 individuals as against 21. However, *relativa* becomes rare further north, and *nivalis* common; conversely, *relativa* is common further south, while *nivalis* is rarely found in southern Canada or in the United States, except along the Rocky Mountains.

According to Mitchell (49), *relativa* is to be found from "North Carolina west to New Mexico and California and northward throughout Canada to Mackenzie and Newfoundland"; his records, however, include only 3 localities from northern Canada (Slave Lake, Alta., and Fort Simpson and Fort Providence in Mackenzie). At hand in the Canadian National Collection there are 122 Canadian specimens of *relativa* females, of which only 4 can be considered as at all northern (Athabasca, Bear L., Shaftesbury and Smoky River Crossing, Alta.; all collected by E. H. Strickland between August 18 and 24, 1915); moreover, these localities are still within the Canadian Zone, in which *relativa* is common.

Published records of Mitchell (48, 49, 50) show that *nivalis* is almost entirely restricted to northern Canada with a southward extension along the Rocky Mountains, the holotype being taken at the 9000 ft. level on Pikes Peak, Colo. Exceptional localities are Lake Nipigon, Ont., Montreal, P.Q. and Vancouver, B.C. (47), and Maine (51). Additional Canadian records of *nivalis* females are Cameron Bay, Great Bear Lake (July 6 to 27, 1937, T. N. Freeman); Tazin River (July 12, 1914, F. Harper); Fort Wrigley, Mackenzie River (July 20 to 25, 1922, C. H. Crickmay); Lesser Slave Lake, Alta. (August 17, 1915, J. M. Swaine); Jasper Park, Alta. (September, 1916, F. Johansen); Waterton, Alta. (August 14, 1921, E. H. Strickland); Vernon, B.C. (August 2, 1923, D. G. Gillespie) and Gaspé, P.Q. (August 24, 1932, E. B. Watson). The comparative rarity of *nivalis* in southern and eastern Canada is emphasized by the vastly greater collecting that has been carried out in this area than in the north.

At White Fox the visits of these bees to certain flowers were observed (Table 4). Fireweed attracted 19 females of *relativa* and only two of *nivalis;* almost all *relativa* specimens were taken on one of two successive days; the catch for each day was taken at a different locality and at each a single specimen of *nivalis* was taken. Sow thistle attracted 7 females of *relativa* but none of *nivalis*, all records being taken on the same day. As the total collections in 1944 for the White Fox area were 35 for *relativa* and 21 for *nivalis*, the figures for these visits suggest that the two forms have definite flower preferences and are specifically distinct.

The nesting habits may be used in evaluating these two forms, although the various species of leaf-cutter bees may not be entirely restricted to one type of nesting site, such as earth, hollow plant stems or logs. According to Guignard (34), *relativa* (*brevis* Cr.) nests in sunflower stems, although this species has also been reared from a tunnel in a bank (Hicks, 35). At White Fox 10 females of *nivalis* were reared to the adult stage, but not one of *relativa* (Table 5). It is perhaps also notable that the nests of *nivalis* (and *inermis*) were uniformly blocky and neat, made from poplar leaves pressed closely together. A series of three joined nests with three associated

relativa females are at hand; these nests are narrower, irregularly shaped and made apparently with poplar leaves inside and rose leaves outside. The apices of the rose leaves project untidily from the sides of the nests. The original site of the *relativa* nest is not known.

These biological data, showing apparent differences in nest-building and in flower preferences, are not sufficiently numerous to allow *nivalis* to be considered without doubt as specifically distinct. However, the two forms are treated so, as a matter of caution and convenience.

Among the species reported by Knowles (37) on alfalfa was *M. montivaga*. The specimens, however, have proved to be *M. relativa*. The name *frigida*, too, should be substituted for that of *vidua*, as used in the papers of Knowles (37) and Mitchell (49), since the name *frigida* has priority (Mitchell, 51). Similarly, in the genus *Coelioxys* the name *dubitata* has priority over *rufitarsis*, since Viereck (73) appears to be the first reviser. The identity of the male of *Coelioxys moesta* is discussed under the heading "Parasites and Predators."

THE VALUE OF VARIOUS BEES IN TRIPPING

Gathering of Statistical Data

The amount of tripping and the seed yield of alfalfa at White Fox have been correlated by Knowles (37) with the numbers of bumble bees, of leaf-cutter bees and honey bees. Knowles' work was continued during 1943 by the junior author and during 1944 by both authors.

During 1943, 33 fields were sampled between July 14 and August 11, while, during 1944, 30 fields were examined between July 20 and August 1. The density of the bee populations in each field was determined by counting the number of bumble bees, leaf-cutter bees and honey bees found in 40 squares, each approximately 8 feet square and 10 to 20 yards apart. No attempt was made to recognize the different species. While bumble bees are active at lower temperatures than either leaf-cutter bees or honey bees, yet no records were taken with the temperature below 67° F., when the leaf-cutter bees were inactive in the field; consequently the estimations of the total activity of the bumble bees are low.

The amount of flower-tripping was estimated by counting the number of freshly tripped flowers on 200 racemes, 5 being taken from each of the 40 sampling squares. These racemes were average in size and were picked at random within the square. A flower was considered as freshly tripped only until the banner petal began to fold. According to Tysdal (72) this occurs about 2 hours after tripping, so that records were not taken until the temperature had been above 67° F. for at least 2 hours, thus ensuring that the activities of the leaf-cutter bees would be fully recorded.

The comparative yield of seed from each field was found by averaging the yield from 20 plots, each a square yard in area and chosen at random.

The various correlations between the different factors are shown in Table 1, while the numbers of each group of bees in relation to the number of tripped flowers are summarized in Table 2. These figures are discussed below, according to the type of bee.

TABLE 1.—CORRELATION VALUES BASED ON THE NUMBER OF BEES IN 40 SAMPLES, EACH OF ABOUT 64 SQUARE FEET, AND OF TRIPPED FLOWERS ON 200 RACEMES FROM EACH FIELD. SEED YIELDS ESTIMATED FROM 20 SQUARE YARD SAMPLES FROM EACH FIELD

Type of correlation	Comparison	Year	
		1943, N = 33	1944, N = 30
Simple	Tripping vs. total leaf-cutter and bumble bees	.72†	.61†
Simple	Tripping vs. leaf-cutter bees	.72†	.57†
Simple	Tripping vs. bumble bees	.53†	.44†
Simple	Tripping vs. honey bees	.12	−.05
Simple	Leaf-cutter vs. bumble bees	.36*	.32
Simple	Seed yield vs. leaf-cutter bees	.50†	—
Partial	Tripping vs. bumble bees	.39*	.34
Partial	Tripping vs. leaf-cutter bees	.67†	.51†
Partial	Leaf-cutter bees vs. bumble bees	.01	.07
Multiple	Tripping vs. all bees	.78	.63†

* Exceeds 5% point.
† Exceeds 1% point.

TABLE 2.—NUMBER OF BEES IN 40 SAMPLES, EACH OF ABOUT 64 SQUARE FEET, AND OF TRIPPED FLOWERS ON 200 RACEMES FROM EACH FIELD

Year	No. of fields	Av. no. honey bees	Av. no leaf-cutter bees	Av. no. bumble bees	Av. no. leaf-cutter and bumble bees	Av. no. tripped flowers	Av. no. tripped flowers per wild bee
1943	33	13.1	3.1	5.2	8.3	93.1	11.2
1944	30	7.3	3.0	2.7	5.7	64.9	11.4

HONEY BEES AS TRIPPING AGENTS

Honey bees are usually recorded as being of little or no importance as tripping agents in the northwestern portion of North America (Gray, 33; Knowles, 37; Piper, *et al.*, 59; Salt, 65; Sladen, 68; Tysdal, 72). However, in Manitoba, Lejeune and Olson (38) observed that one day 12 honey bees tripped 28% of the 114 flowers visited by them, on the next day 17 bees tripped 17.1% out of 105, and two days later 16 bees tripped 0.0% out of 158; no honey bees were seen tripping during the remainder of the season. A somewhat similar occurrence was reported in New South Wales by Dwyer and Allman (17).

In the White Fox area large numbers of honey bees were observed visiting alfalfa flowers. In most instances the bees approached the flower from the side of the keel, as reported by various other investigators (17, 33, 38, 65). However, a few honey bees were noted which regularly approached the flower between the keel and banner petals and almost invariably tripped the flower. They were slower than wild bees, principally because they usually were trapped by the violent tripping mechanism and had some difficulty in extricating themselves. According to Gray (33), the honey

bee enters from the side of the flower because the tongue is otherwise too short to reach the nectaries of the alfalfa flower. A scarcity of other pollen sources may force honey bees to collect it from alfalfa flowers, which would not ordinarily be visited for this purpose. This might prompt the behaviour of the exceptional individuals noted at White Fox, as well as accounting for the results of Lejeune and Olson (38), and of Dwyer and Allman (17); the latter reported 27.39% of the flowers set pods where a hive of honey bees was caged with relatively few alfalfa plants.

Tripping by honey bees seems to be rare and to be caused by abnormal conditions; these may include the scarcity or absence of preferred pollen and the occurrence of hot and dry weather. The presence of self-tripping plants of alfalfa may also cause records to be incorrectly attributed to honey bees visiting at the time of tripping. Furthermore, honey bees have a strong tendency to visit only one species of plant during a flight and therefore they can appear unduly important.

At present at White Fox honey bees are unimportant as tripping agents, the statistical data obtained supporting the field observations. Knowles (37) reported a significant value of + .54 between the amount of tripping and the number of honey bees in 1942 but believed that this was caused by the attraction of honey bees and leaf-cutter bees to the same field. As shown in Table 1, correlations of + .12 and − .05 were obtained in 1943 and 1944, showing the unimportance of honey bees in tripping, even though Table 2 shows that there were more honey bees present than leaf-cutter bees or bumble bees.

Honey bees may be indirectly responsible for a reduction in the number of visits by other bees. It has been suggested by Salt (65) that they rob the flower of its nectar, probably making it less attractive to insects that can pollinize it. This of course would occur only when the alfalfa crop is secreting merely a small amount of honey, either during the cooler parts of the day or else before or after the main bloom.

Furthermore, the honey bee may be detrimental to the setting of alfalfa seed because of the effects of its foraging upon the food supplies of the wild bees. Indeed, Pearson (58) has commented upon the honey bee as follows: "So efficient is it as a collector of pollen and honey and so ubiquitous has it become, there can be no question but what its inroads cause a serious diminution in the food supplies of native bees, particularly in bad seasons." This statement was based upon the author's experience with the bees in Wisconsin, and was not supported by data. Nevertheless, it should be borne in mind that bee-keeping is a common practice in the White Fox district and that Pearson's opinion may be applicable here, at least when pollen and nectar are scarce.

On the other hand, honey bees may be of considerable value in cross-pollinating self-tripping alfalfa plants such as those described by Armstrong and White (4), if a strain of this type were developed. At Saskatoon, honey bees have been observed to visit freely the tripped flowers on these plants. In addition, a preliminary experiment indicated that pollination with foreign pollen one hour after tripping, and possibly longer, will result in cross-fertilization. By the selection of self-sterile, self-tripping strains of plants, tripping would occur independently of insect visitation and cross-pollination might be effected by honey bees.

Wild Bees as Tripping Agents

Wild bees have long been considered as important in the setting of alfalfa seed and are virtually the only group of insects associated with tripping. In the prairie provinces of Canada the value of wild bees has been studied by Sladen (68), Gray (33), Salt (65), Lejeune and Olson (38) and Knowles (37); these workers emphasized the importance of leaf-cutter bees and bumble bees. In the northern part of North America other groups of bees that trip alfalfa belong in the genera *Nomia* (72), *Andrena* (1, 18), *Halictus* (18) and *Anthophora* (68).

At White Fox the importance of bumble bees and leaf-cutter bees has already been pointed out by Knowles (37). This work was continued for two more seasons. The results are presented in Tables 1 and 2 and amply confirm Knowles' conclusions. Both simple and partial correlations suggest that the leaf-cutter bees form the more valuable group. However, high correlations were obtained between bumble bee populations and tripping; furthermore even the partial correlation, where the effects of leaf-cutter bees and honey bees were held constant, was significant in 1943. Tysdal (72) found that bumble bees varied from 38 to 80% in effectiveness of tripping. While our correlation values indicate that leaf-cutter bees are more important than bumble bees, the summary presented in Table 2 suggests that equal value should be attached to each group. The average number of flowers tripped per field in 1943 was considerably greater than in 1944. Leaf-cutter bees were equally abundant in each year but bumble bees were more numerous in 1943 than in 1944. Yet, when the number of tripped flowers is based upon the total number of wild bees present, there is no essential difference in the two years.

In any comparison between the relative value of leaf-cutter bees and bumble bees it should be kept in mind that bumble bees work at lower temperatures and reduced sunlight, and, consequently, for longer periods each day. Had some records been taken at temperatures unfavourable only to leaf-cutter bees, bumble bees would have undoubtedly been shown to be more important than the tables suggest.

On the other hand, bumble bees seem to show considerable variation in population from year to year. In 1942 their numbers in the alfalfa fields at White Fox were considered as very small by Knowles (37); in 1943 they were more numerous in alfalfa fields than leaf-cutter bees and were twice as numerous in 1943 as in 1944 (Table 2). The numbers of bumble bees in red clover, too, have been shown by Morrison (54) to vary excessively from year to year in Quebec.

A large number of observations were made on the tripping abilities of individual bees. The method used was to record the tripping activity of a particular bee, which was then captured, given a number corresponding to its record, and later identified. Notes were taken on the habitat and the behaviour in regard to tripping. In some cases a record was made of the number of alfalfa flowers visited per minute, these data being summarized in Table 3.

Among the species of leaf-cutter bees, *Megachile frigida*, *M. melanophaea*, *M. nivalis*, *M. relativa*, *M. gemula*, *M. inermis* and *M. latimanus* were observed actively tripping alfalfa flowers; as shown in Table 3, all species

TABLE 3.—SUMMARY OF OBSERVATIONS ON THE NUMBER OF ALFALFA FLOWERS VISITED PER MINUTE BY DIFFERENT SPECIES OF BEES[1]

Species	Number of observations	Rate per minute	
		Average	Range
Megachile frigida	28	18	10–34
M. melanophaea	1	15	—
M. inermis	4	15	8–27
M. latimanus	5	20	16–23
Bombus borealis	3	21	12–27
B. rufocinctus	1	20	—
B. terricola	7	17	12–28
B. vagans	2	16	15–16
B. ternarius	3	13	10–17

[1] *M. nivalis* and *relativa* were also found to be fast and efficient in tripping blooms.

tripped a high percentage of the flowers visited but *M. inermis* (with the exception of one individual) was much slower in its movements than any other species. Although well represented in the general bee population, neither *nivalis* nor *relativa* is included in Table 3. Both species are fast and efficient trippers but are very active and easily frightened so that, although many attempts were made to take records, the bee always disappeared before it had been observed for a full minute. Seventeen records were taken of *M. pugnata* but in no case was it found visiting alfalfa, although it was often collected on other flowers growing in alfalfa fields. This species seems to be of no economic importance to alfalfa seed-setting, especially as Robertson (63) has recorded it as restricted to certain of the Compositae. Very few detailed observations were made of the relative tripping efficiency of males and females of the same species. However, many males of *M. frigida* were taken on alfalfa flowers; several were actively tripping, although in general they were not as efficient as the females and in several instances approached the flower from between the keel and wing petals in the same manner as honey bees, presumably seeking nectar rather than pollen.

The bumble bee species, *Bombus borealis*, *rufocinctus*, *terricola*, *vagans* and *ternarius* visited alfalfa and all were more or less effective as tripping agents (Table 3). *B. huntii* was observed on alfalfa but not tripping, and *perplexus* and *californicus* were seen only on other host plants but not in sufficient numbers to form any opinion as to their flower preference. In addition, the guest bumble bees, *Psithyrus suckleyi* and *ashtoni* were observed tripping. *P. insularis* was collected on alfalfa but was not observed to trip any flowers.

Among other wild bees, *Coelioxys* was observed visiting alfalfa. Two individuals tripped flowers but they did so very slowly and awkwardly and usually were trapped by the tripping mechanism. *Anthophora furcata*, although a common visitor, was only once seen to trip alfalfa flowers; Sladen (68) has also reported *furcata* on alfalfa but only at Ottawa. This

species has a very long tongue and, although it often approaches the flower between the banner and keel petals, it is still able in this position to extract nectar without tripping.

Since the speed at which an individual bee works is an important factor in evaluating its effectiveness as a tripping agent, records were taken of the rate at which bees visited alfalfa flowers. The data, summarized in Table 3, indicate that individual bumble bees and leaf-cutter bees visited alfalfa flowers at about the same rate. The difference in efficiency appears to be in the higher percentage of flowers tripped by the leaf-cutter bees. However, certain individual bumble bees were as equally efficient in tripping as the best of the leaf-cutter bees.

THE ECOLOGY OF VARIOUS ALFALFA BEES

In any study of the effects of a changing habitat upon an insect population it is necessary for the whole problem to be reviewed, even though only parts can be examined immediately. The present report is therefore preliminary in nature, covering only those phases that could be dealt with best at the present time. However, indications of subordinate problems and suggestions of possible remedies have been included; these are considered as forming an important, and frequently omitted, part of a preliminary report on a problem.

The establishment of alfalfa as a seed crop in northern Saskatchewan has had two important results upon the native bees:—

1. The establishing of this and other crops has increased greatly the amount of raw land that has been broken, thus destroying many bees, much of their native food, and many of their nesting sites.
2. The growing of this seed crop has made an abundant supply of food available to many native bees, including those needed to trip the blossoms. This food, however, is produced only for a part of the season.

Paradoxically, the grower has ravaged the bees upon which he depends for the fertilization of his alfalfa flowers, although producing a temporary abundance of food for them.

The preservation of natural nesting areas adjacent to the alfalfa has already been urged in order to maintain the numbers of bees as trippers (Salt, 65; Tysdal, 72; Knowles, 37) and this is perhaps all that is needed in certain areas. Nevertheless, such a policy may not necessarily maintain the alfalfa bees in satisfactory numbers. As emphasized by Nicholson (56) and Smith (70), the average density of an insect population fundamentally is regulated by the competition for space and food, and by factors such as parasites, predators and disease. These phases should be considered in any attempt to maintain or increase populations of alfalfa bees.

Plant Habitats

Before factors such as space, food and inquilines can be assayed, the number of natural habitats must be noted, as well as their proportions and their value in providing shelter and food. In the White Fox area the

natural vegetation and soil types conform to three general types. By far the greater area is dominated by *Populus tremuloides* Michx.[1] (aspen poplar) and *P. tacamahacca* Mill. (balsam poplar) with an occasional sprinkling of *Picea glauca* (Moench) Voss. (white spruce). With these trees are associated the following shrubs and herbs that probably are sources of pollen and nectar: *Grossularia* spp. (gooseberries), *Ribes* spp. (wild currants), *Distegia involucrata* (Richards.) Cockerell (swamp honeysuckle), *Mertensia paniculata* (Ait.) Don. (bluebell), *Lathyrus* spp. (wild sweet pea), *Vicia americana* Muhl. (wild vetch), *Svida instolonea* A. Nels. (dogwood), *Chamaepericlimenum canadense* (L.) Aschers. & Graebn. (bunchberry), *Fragaria glauca* (S. Wats.) Rydb. (wild strawberry), *Rubus melanolasius* Focke (wild raspberry), *Chamaenerion spicatum* (Lam.) S. F. Gray (fireweed), *Aster* spp. (wild aster) and *Solidago* spp. (goldenrod). *Taraxacum officinale* Weber (dandelion), *Sonchus arvensis* L. (sow tnistle) and *Trifolium hydridum* L. (alsike clover) are commonly found in cultivated fields and along roadsides. This general area is characterized by clay and clay loam soils.

Smaller areas throughout the district, composed of light sandy soils, are dominated by *Pinus Banksiana* Lamb. (jackpine). Very few species of plants yielding nectar and pollen are found in this soil type, the only important ones being *Arctostaphylos Uva-ursi* (L.) Spreng. (bearberry), *Vitis-Idaea punctata* Moench. (sand cranberry) and *Cyanococcus canadensis* (Richards.) Rydb. (blueberry). However, a few of the species from the poplar habitat are sparsely represented here too, perhaps because the sandy areas do not cover large acreages and the poplar vegetation is often nearby.

Another very distinct vegetative type occurs on poorly drained peat soils and is commonly known as muskeg or swamp vegetation. The dominant trees are *Larix laricina* (DuRoi) Koch (tamarack) and *Picea Mariana Mill.* B.S.P. (black spruce). Commonly associated flowering plants which may be sources of pollen and nectar are *Betula* spp. (swamp birch), *Ledum groenlandicum* Oeder (Labrador tea), *Andromeda polifolia* L. (bog rosemary), *Kalmia polifolia* Wang. (pale laurel), *Oxycoccus palustris* Pers. (swamp cranberry), *Rubus Chamaemorus* L. (cloudberry) and *Xylosteon caeruleum* (L.) Dum.-Cours. (blue fly honeysuckle). No critical examination was made of this habitat and only a few bees were collected from it. However, it occasionally occurs near alfalfa fields and probably should be considered in any future study.

Wherever possible, collections were classified according to their proximity to the poplar and jackpine habitats. A summary of the data obtained is presented in Table 4, together with data on the flowers visited by individual bees. Plant records excluded individually from this table are as follows:—

Vicia americana Muhl. (Wild Peavine): *B. rufocinctus*, *B. vagans*.
Melilotus alba Desv. (White sweet clover): *B. ternarius*, *B. rufocinctus*.
Agoseris sp., ? *scorzoneraefolia* (Schrad.) Greene: *M. pugnata*.
Agastache sp. (Giant hyssop): *B. ternarius*, *B. vagans*.
Castilleja sp. (Indian paint brush): *B. californicus*.

[1] These botanical names conform to the usage in Rydberg's Flora of the Prairies and Plains of Central North America. New York Botanical Garden, N.Y. 1932.

TABLE 4.—HOST PLANTS AND HABITAT RELATIONSHIPS OF WILD BEES IN THE WHITE FOX AREA

Species of wild bee	Number of records						Total number of bees observed	Habitat		
	Alfalfa	Sow thistle	Dandelion	Fireweed	Goldenrod	Other* plants		Poplar	Jackpine	Total observed
Megachile frigida	85	3	0	30	0	4	122	88	37	125
M. melanophaea	4	0	0	0	0	0	4	2	3	5
M. gemula	2	0	0	1	0	0	3	1	0	1
M. nivalis	5	0	1	2	0	0	8	18	0	18
M. relativa	8	7	1	20	0	1	37	32	2	34
M. inermis	4	9	2	8	0	2	25	26	1	27
M. latimanus	13	3	0	0	0	0	16	1	15	16
M. pugnata	0	6	6	0	0	5	17	12	3	15
Anthophora furcata	8	0	1	0	0	7	16	5	0	5
Bombus huntii	1	0	0	1	0	0	2	1	0	1
B. borealis	8	2	0	1	0	2	13	8	4	12
B. californicus	0	0	0	0	0	1	1	1	0	1
B. perplexus	0	0	0	2	0	0	2	2	0	2
B. rufocinctus s.l.	13	10	0	1	0	4	28	14	12	26
B. terricola	45	4	1	1	3†	3	57	36	12	48
B. vagans s.l.	4	2	0	5	0	3	14	10	2	12
B. ternarius	16	6	1	5	3	8	39	21	5	26
Psithyrus ashtoni	1	0	0	0	0	0	1	1	0	1
P. insularis	2	1	0	0	0	0	3	1	0	1
P. suckleyi	3	1	0	0	0	0	4	1	3	4
Totals	222	54	13	77	6	40	412	281	99	380

* The plants included in this column have been listed previously on p. 398.
† Males.

As shown in Table 4, some species of bees showed a decided preference for distinct habitats. This was not shown as strongly in *Bombus* as in *Megachile*, although the associations of *Bombus* may be masked by their ability to forage far afield. In *Megachile* the species *inermis*, *relativa* and *nivalis* frequented only the poplar habitat and *latimanus* the jackpine areas, while *frigida* was commonly found in both and *melanophaea* infrequently in both. No satisfactory explanation is available for the apparent ecological restriction of some of these bees, although more complete information on their habits of nesting and foraging might clear up the point.

No attempt was made to correlate the sampling of the species of alfalfa bees with the distance from sod and bush. This may be difficult to undertake satisfactorily, although the data would be valuable in determining how close alfalfa fields should be to nesting areas and to other food supplies, in order to gauge the probable efficacy of methods used to increase the numbers of alfalfa bees.

NESTING

Natural Nesting Sites

As already shown in Table 4, the species of *Megachile* that trip alfalfa prefer certain habitats. This is related to the places in which they nest. The only species restricted to the sandy jackpine area is *M. latimanus*

which nests in the ground (Mitchell, 50; Pearson, 58). *M. melanophaea* was found in both the jackpine and poplar areas but, as it also nests in the soil (Graenicher, 30), it is likely to be associated with the better-drained sandy soils of the jackpine habitat.

Three important species were closely associated with the poplar area only. These are *inermis*, *nivalis* and *relativa* and the first two have been reared at White Fox from logs. No previous nesting records are available upon *nivalis* but *inermis* has been reared from rotten apple wood by Sladen (69). *M. relativa* has been reared from a tunnel in a bank by Hicks (35) and has been recorded as possibly nesting in logs (Mitchell, 50). Guignard (34) has recorded *brevis* Say as nesting in sunflower stems, the only specimen placed as such in his collection in Ottawa proving to be *relativa*.

The remaining, and most important, species is *frigida*, which occurs commonly in both the poplar and jackpine areas. It has been recorded as nesting in a rotten log (Mitchell, 49). At White Fox many *frigida* adults were found in holes in logs but no individuals were reared, apparently because the nest-building females were ousted by females of *nivalis* and *inermis*. The numerous locality records of Mitchell (49) show the affinity of *frigida* to wooded areas, apparently including some river banks in otherwise typical prairie areas.

The records in Table 4 indicate that bumble bees, too, have certain preferences in habitat. However, these preferences are not likely to be closely related to nesting, since bumble bees normally nest either at the ground surface or below it (Sladen, 66; Plath, 60). Furthermore, as bumble bees are able to range far afield because of their powerful flight, the records for *Bombus* may reflect their preferences for certain flowering plants rather than for a type of nesting area.

From these nesting records it is evident that in northern Saskatchewan many nesting sites must have been destroyed by breaking up the raw land. Furthermore, as the farmer normally breaks the most open parts of his land first, and as these grassy and lightly timbered areas are sunny and contain all of the nesting sites, a disproportionately high number of nests and nesting sites are usually destroyed with the advent of farming.

Since the restoration of these sites is at best a gradual process, it must often be necessary to preserve the remaining areas, as well as to supplement them as far as possible. The locating of alfalfa fields near residual nesting areas and the preservation of some brush along the fences and roadsides were advocated by Salt (65), who also noted that these residual areas should be undisturbed by both farm machinery and flood waters. Possibly the most valuable method of encouraging nesting is the broadening of the narrow sunny strips that normally surround a field. Such strips could be made more attractive to bees by various methods that are discussed later.

Increases in the number of nesting sites may not necessarily result in the presence of more bees, since factors such as food may be of greater importance. Nevertheless, even if there were no scarcity of nesting sites, the establishing of new nesting areas in or near the alfalfa may still result in higher yields of alfalfa seed. The yield of seed is frequently controlled by the early fall frosts and the early tripping of the alfalfa therefore is of

considerable importance. The early tripping by bees is affected by the amount of sunshine and warm weather, by the time taken by the bees to find nesting sites, and by the time needed to fly between the nest and the alfalfa. The limitations set by the last two factors can be modified by suitable nesting areas being close to the alfalfa.

Bees may spend considerable time in looking for suitable nesting sites. A queen bumble bee may spend weeks in this search (Plath, 60) and any saving of time during the spring means the earlier production of workers in the colony and a great increase in the number of worker bees available to trip the earlier bloom. Leaf-cutter bees, however, have to search intermittently throughout the season for nesting sites so that the establishment of sufficient nests near the alfalfa would materially aid the leaf-cutter bees at this time.

Nevertheless, the locating of sufficient nesting sites near the alfalfa may not be entirely advantageous for alfalfa bees. Apart from the dangers of possible overcrowding, such as increase in parasitism and disease, the bees may have to fly great distances for other food when the alfalfa is not in bloom. Thus, the grower should not only make sufficient nesting grounds available to the bees but also see that the early food supply is close. The value of both bumble bees and leaf-cutter bees to the grower should then be considerably greater during the critical time of the early blooming of alfalfa.

Artificial Nesting Sites

The increasing of bee populations by preparing artificial nesting sites has been advocated by several authors, although no practical work has been carried out in a style that would benefit the seed grower. The spreading and rolling of gravel has been suggested as a means of providing nesting places for *Megachile perihirta* Ckll. in southern Alberta (Sladen, 68); as Sladen believed this species to nest in steep gravel banks, the gravel should not be strewn but rather piled in hollows and covered with soil on all but the sunny side. Such methods do not appear of use at White Fox. It is also of interest to note that *perihirta* is believed by Hicks (35) to nest in non-sandy soil with only a few pebbles in it.

The growing of hollow-stemmed plants may be useful in providing nest sites for *Megachile* species. Pieces of elder stem with the pith removed have been used by Balfour-Browne (3), who also found glass tubing plugged at one end to be of value. At White Fox the stems of *Heracleum lanatum* Michx. (cow parsnip) were tied in small bundles and left in sunny places; however, no bees were attracted. As noted above, sunflower stems have been selected for nesting by *relativa* (Guignard, 34). Old mullein and sunflower stems have also been used by *montivagus* (Hicks, 35), while upright stems of both sumac and burdock were found attractive to *M. centuncularis* L. (*infragilis* Cress.) by Graenicher (31). Since there is some suggestion, as shown above for *relativa*, that species of leaf-cutter bee may perhaps be found in both log tunnels and the hollow stems of plants, it may be advantageous to plant hollow-stemmed plants in the fringe around the alfalfa field. The ease with which cultivated sunflowers can be grown suggests that the old stems of this plant may be scattered advantageously along the edges of the field.

Species of *Bombus*, too, have been induced to use artificial nesting sites placed in the ground. This phase has been investigated in England by Sladen (66) and his methods have been adapted by Frison (23) and Plath (60). Great variation occurs in the suitability of species to semi-domestication in these nests (Frison, 25 to 28) and none of the species studied by Frison are known to visit alfalfa. The value of such nests in the field is problematical, depending probably upon the extent to which the colonies could flourish when neglected by man.

As bumble bees often nest under boards and duckboards, nesting may be encouraged by placing these in well-drained open spaces near the alfalfa fields. The boards would also protect the nests from excessive dampness and flooding, which Sladen (66) reported as causing great losses in bees. The boards are favourite nesting places for mice and the deserted nests are very attractive to queen bumble bees (Sladen, 66; Plath 60, Rau, 62). The placing of empty mouse nests in a natural manner under these boards would encourage such nesting; the old nests of small birds have also been found attractive in making nests (Frison, 25). However, no testing was carried out on this at White Fox.

At White Fox the nesting habits of wild bees were studied only for the alfalfa species nesting in logs and, to a very minor extent, in stems. This choice was made because these species were considered to have less chance than the ground-nesting species of finding nesting places, because this group included the valuable species *frigida* and because some success in this had already been obtained by Mr. W. D. Clarke, a local grower.

The method used by Mr. Clarke was both simple and practical. About July 30, 1943, approximately 100 holes were drilled into logs of white spruce by Mr. Clarke on his farm about 20 miles north of White Fox. Most of the logs were part of his log cabin but one of them was part of a fallen tree that was lying in a horizontal position about 2 feet above the ground. The holes in these logs were about 4 inches deep, $\frac{1}{4}$ inch in diameter, spaced 2 to 3 inches apart and slanted upwards slightly to prevent water running into them. They were located on the south side of the logs since it was observed that leaf-cutter bees were not attracted unless the holes were exposed to a maximum amount of direct sunlight. Almost immediately, leaf-cutter bees investigated the holes and within 2 or 3 days were carrying in pieces of leaf. Within the next 2 or 3 weeks, at least half of the holes were occupied and by the end of August several had been sealed with mud plugs. A portion of fallen tree containing several sealed holes was taken to the laboratory at Saskatoon and about October 10 two adult *nivalis* bees emerged from one of the holes. In the spring of 1944 a close watch was kept on the holes in the log cabin. The first bee emerged on June 6 and emergence from several other holes continued for several days; this emergence was probably premature because of the heat from the house; however, *M. nivalis* was collected, June 13 and 15 in 1943, while visiting wild flowers. Late in the season many of these same holes were cleaned and reoccupied by bees.

During 1944 approximately 2000 holes were bored in logs and stumps at various points in the White Fox area by Mr. Clarke and the authors. White spruce, jackpine, white poplar and cedar were used. Later, bee

nests were found in the logs of all these trees. About June 29, bees were found resting in the holes during the evening and a few days later nesting activities were noted. A number of bees actively engaged in building nests in these holes were captured and *M. frigida*, *inermis* and *nivalis* later were identified from these specimens. While some of the logs were well filled with nests, less than half of the tunnels in other logs were used. The number of tunnels in a log varied from 20 to 60, depending upon the size of the log. The logs were separated by at least several hundred yards. Two of the best filled logs were placed on their sides about a foot off the ground. However, while bees search for nests at this height they can nest in artificial holes 3 and 4 feet above the ground and they frequently investigate holes in dead stubs of trees to a height of 10 to 15 feet. A log containing 80 tunnels was placed along the edge of an alfalfa field and, as nearly all these tunnels contained nests later, this may be a sound practice to ensure more uniform tripping.

The number of nests in each tunnel varied considerably. Those of *inermis* averaged 4.2 from 14 holes and showed a range of 2 to 7; those of *nivalis* averaged 3.5 from 23 holes, ranging from 1 to 6. These figures have a practical bearing upon deciding the most suitable depth for the holes; at White Fox these were about 6 inches deep and 5/16 inches in diameter. Since the nests are somewhat under ½ inch in length, this size appears to be long enough for these species.

In order to study the insects to be found in *Megachile* nests, parts of 5 of these logs were shipped to Ottawa in the late autumn. The logs were kept outside under snow until January, and then gradually brought up to room temperature. The logs were split to take out the nests, each of which was placed in an air-tight tin with its record of the hole from which it came and its position in the tunnel. The rearings from these nests are shown in Table 5.

TABLE 5.—REARINGS FROM BEE CELLS IN ARTIFICIAL LOG COLONIES

	Log					Totals
	1	2	3	4	5	
Megachile inermis ♂	4	6	—	—	—	10
Megachile inermis ♀	—	—	—	—	—	0
Megachile nivalis ♂	—	8	14	—	—	22
Megachile nivalis ♀	—	—	8	1	1	10
Coelioxys ♂	—	-	4	—	—	4
Coelioxys ♀	—	—	5	—	—	5
Ichneumon sp. ♂	—	—	—	1	1	2
Ichneumon sp. ♀	—	—	—	4	—	4
Chalcidoid colony	—	1	—	2	—	3
Anthrax	—	2	—	—	—	2
Physocephalus	—	—	—	1	—	1
Mould	1	—	—	2	—	3
Total number of bee cells	5	17	31	11	2	66

The immature bees, arbitrarily defined as those in which the sex could not be externally recognized, were identified to species, with the exception of one individual, by the mandibular teeth of the larva and by the colour and texture of the cocoon. The cocoon is weak and pale yellow in *inermis* but sturdy and dull red in *nivalis*. Another guide was the identification of other nests in the same tunnel, since the nests in each appeared to be made by the same individual bee. Belief in the individual occupation of a nesting hole was supported by the adult bees emerging from each representing, with only one exception, the same sex.

The *Megachile* bees reared from these nests belonged to only two species, *nivalis* and *inermis*. The absence of *frigida* was surprising since many individuals of this species showed great interest in the tunnels. About the first of July only *frigida* was found in the logs, twelve males and eight females being taken at random for identification. Furthermore, at this time many other males were seen facing outwards at the opening of the tunnels and these were readily distinguished from *nivalis* and *inermis* by their enlarged, bright yellow protibiae. Presumably, the females of *frigida* are not as aggressive as those of *inermis* and *nivalis* and therefore allow the latter to appropriate the tunnels selected by *frigida* for nests. Possibly slightly smaller tunnels would have the effect of excluding *frigida* and *inermis*, which are somewhat larger species, should this be thought desirable.

This substitution by *inermis* would seem to be a disadvantage because this species is not only a slow tripper (Table 3) but also, according to Table 4, is not common on alfalfa, preferring sow thistle and fireweed. Although *nivalis* is a quick and efficient tripper, the few records of its flower visits (Table 4) are not sufficient to soundly establish this species as a regular visitor to alfalfa. Indeed, if the suggestion of Mitchell (51) is correct that *nivalis* may be a form of *relativa*, then *nivalis* would appear to visit other plants more frequently than alfalfa. On the other hand, there may be plenty of small natural tunnels available for *nivalis* but only a few tunnels large enough for *inermis* and *frigida;* in this case any increase in the nesting of the two latter species would result in more tripping. The immediate results of using these logs are therefore of uncertain value to the grower of alfalfa seed.

While progress has been made by using these logs, yet further study is needed before the method can be freely advocated. Consideration must be given to their attractiveness to different species being perhaps affected by the width of tunnel. The undesirable species may be excluded to a great extent by placing the logs within the fields. Possibly the tunnels should be scattered thinly around or in the field to reduce parasitism, to reduce the flying-time of individual bees and to reduce irregularities of seed-setting within the field. The present methods can therefore be considered as practical but needing modifications in order to conform more closely with the biological needs and habits of this group of alfalfa bees.

FORAGING

The supplies of food available to the alfalfa bees must of course be considered in any program for increasing or maintaining bee populations. Under natural conditions in the nearctic area there is a large assortment of bloom in both spring and fall, while the supply in late summer is scanty.

The advent of farming at White Fox has greatly reduced the early and late blooms, with the exception of dandelion which has now invaded practically all roadsides and older alfalfa fields and has both early and late flowering periods. Summer bloom has been increased many times by the introduction of farm crops and weeds such as alfalfa, clovers and sow thistle. The grower of alfalfa seed thus needs to know (1) how much the alfalfa bees are affected by the losses in native flowers and (2) to what extent these bees visit other plants while the alfalfa is flowering. The answers are not simple, since bumble bees and leaf-cutter bees have quite different life cycles, and since the species within these two groups vary in their flower preferences. The two major groups are therefore discussed separately.

During the summer months the alfalfa bees usually have an abundance of food supplied by cultivated crops and by weeds. The bees must then be restricted to alfalfa bloom as far as is reasonably possible. According to Salt (65) the blossoming of the alfalfa-seed crop should be accompanied by the cutting of sweet clover, white Dutch clover and alfalfa hay fields. Red clover grown for seed in plots is also attractive to *Bombus* to some extent although only slightly so to *ternarius*, *terricola* and *rufocinctus* (Morrison, 54). At White Fox among the most prominent flowering plants are dandelion, sow thistle and fireweed. Dandelion is abundant in the alfalfa fields and apparently at present ineradicable. Indeed, from the standpoint of bee populations, eradication of dandelion may be inadvisable since it does not compete strongly with alfalfa in the summer season and may be a useful source of food in the spring and fall which are its normal periods of bloom. Sow thistle may be abundant throughout fields but usually is to be found along adjacent roadsides and nearby waste places. It can be checked by cultural control or mowing. Fireweed occurs chiefly in open spaces after brush-burning and may cover extensive areas. Control by mowing is practical where sticks and stones do not interfere. Otherwise chemical sprays would have to be used if adequate control is to be secured. The effects of these plants upon the flower visiting of various species of alfalfa bees are discussed later.

The amount of food available for alfalfa bees may be locally affected during times of scarcity by the feeding of other wild bees and also of honey bees. As noted previously, the numbers of the latter make the keeping of honey bees on a large scale a possible threat to the growing of alfalfa.

The visits of alfalfa bees to other flowers could be recorded only by carrying out general collections upon selected species of plants and this unfortunately had to be restricted to the time of alfalfa bloom in 1944. Information is therefore needed upon (1) the visits made to plants previous to and later than this time and (2) upon the activity of the bees in gathering pollen or nectar or both. Additional data could be obtained from captured bees by analysing their pollen.

Although no faunal list of *Bombus* has been compiled for Saskatchewan, that of Neave (55) for Manitoba can be adapted to the White Fox area. Records for *Megachile* (subgenera *Anthemois*, *Delomegachile* and *Xantho sarus*) in Saskatchewan are included in Mitchell's monograph of the genus (49, 50, 51).

Records of the flower visits of *Bombus* have been published by Lovell (41), Lutz and Cockerell (42) and Plath (60), while Mitchell (49, 50, 51) has reviewed those for the species of alfalfa bees in the genus *Megachile* found at White Fox. These records are indicative mainly of the possible attractiveness of these flowers at White Fox, because the records are not quantitative, and because the distractive flora at the place of record is not similar to that at White Fox. Nevertheless, records of such visits assume greater importance during periods when pollen or nectar is scarce. The above lists of records for these species suggest that they are capable of feeding from a wide range of plants.

Foraging by Bombus spp.

At White Fox the important species of *Bombus* during 1944 were *terricola*, *ternarius* and *rufocinctus* (Table 4). According to Plath (60), the first two species appear early in the spring and, according to Neave (55), *ternarius* emerges later than *terricola*. A comparison of dates for specimens taken at Ottawa suggests that *rufocinctus* is as early as *terricola* and earlier than *ternarius*. At this time only a small amount of bloom is needed for the population and, as the records of flower visits show that the three species feed from a wide range of flowers, this food could be assured by the reservation of small scattered areas of suitable ground. Such reservations could easily be planted with cuttings of willows and dogwoods, if these plants are not present. The finding of a suitable nesting site is the first task of the queen and this may take as long as 6 weeks (Plath, 60) but, once this is done, brood appears in about 22 days from the time that the eggs are laid (Sladen, 66; Plath, 60). To feed the larvae, the queen brings both pollen and nectar into the nest and, once workers appear, increasing quantities of both foods are needed. The sources of food at this time are presumably native flowers until the sow thistle and alfalfa begin to bloom. As shown in Table 4, dandelion was rarely visited by bumble bees during the alfalfa bloom. These increasing demands for pollen and nectar do not seem to be met by any of the farm plants until the alfalfa bloom. Dandelion begins to flower before alfalfa but, as there are no records of such visits by *Bombus* spp. (41, 42, 60), and as only two visits to dandelion by bumble bees are noted in Table 4, this plant may be unimportant. Since no records were available at White Fox before the alfalfa bloom, dandelion may still be merely less attractive to these bumble bees than alfalfa.

During the alfalfa bloom the alfalfa bees in the genus *Bombus* showed specific preferences towards various farm weeds and native plants. As shown in Table 4, *B. terricola*, the most important species, is only distracted to sow thistle to a minor extent and scarcely at all to dandelion and fireweed. On the other hand, sow thistle is distractive to a serious extent to both *ternarius* and *rufocinctus*. The fireweed clumps used for records were not close to the alfalfa so that competition between the two plant species was not as keen. Nevertheless, fireweed may be distractive to *ternarius* to a serious extent, although this plant flowers somewhat later than alfalfa and therefore may not be important during the first 2 or 3 weeks of alfalfa bloom when most of the seed to be harvested is set. Thus, of the three plants studied, sow thistle seriously distracts alfalfa bees, fireweed is probably of minor importance and dandelion negligible.

The emergence of new queens and males from the nest is accompanied by the distintegration of the colony, the queens mating and seeking hibernation quarters soon afterwards; consequently the number of flower visits by bumble bees diminishes rapidly. The time of emergence of the queens and males varies greatly, this depending both upon the species and weather (Plath, 60). At White Fox a survey of bumble bees was made about August 1, 1944, but the only males taken were 2 of *terricola* on August 1 and 3; in contrast to this a specimen of *terricola* was taken at Crean Lake, Prince Albert National Park, on September 11 by Cockerell (12). As *terricola* has been noted as having early males (Plath, 60), the disintegration of the colonies may not be general for even *terricola* until later. *B. ternarius* is recorded in New England as having males in August and September, a month after *terricola* (Plath, 60) so one may expect *ternarius* to be later at White Fox, too. Records taken at Ottawa for *terricola, ternarius* and *rufocinctus* suggest that the two latter species have males at about the same time.

From these data it is evident that the food requirements of *Bombus* for August and September fluctuate greatly. After about August 15 the alfalfa bloom rapidly disappears and the bees are largely dependent on native flowers. A severe frost in early August is likely to cause the weaker colonies to die out, since, according to Plath (60), food at this time is scarce. Among the blooms visited in the fall by *terricola* and *ternarius* are *Solidago bicolor* L. (Lovell, 40), while these species also were found on goldenrod at White Fox (Table 4). As *Solidago* species often produce much pollen and nectar, even during cool weather (Lovell, 41), beds of these plants should be preserved.

Foraging by Megachile spp.

The feeding habits of *Megachile* differ greatly from those of *Bombus*, since they are solitary bees. Their larvae are not fed in a colony but, instead, the individual nest for each egg is provisioned with enough food to last the young bee until maturity. This habit protects the immature bee against starvation caused by an unseasonable decrease in the amount of suitable bloom, an event that may exterminate whole colonies of bumble bees.

The duration of the nesting time is dependent upon the amount of warm weather, since the adults fly only on warm sunny days. According to the record dates of leaf-cutter bees in the Canadian National Museum, adults in the Canadian Zone fly from about the middle of June until the middle or end of August. However, the length of this period of course is affected by variations in the weather from one season to another.

The shortness of the adult stage in *Megachile* allows the adults of some species to utilize only a few species of plants. Alfalfa bees in the genus *Megachile* may have a tendency towards this condition because (1) alfalfa supplies nectar profusely during warm weather (Lovell, 41), its pollen also being abundant and (2) alfalfa has a long period of bloom unless an unseasonable frost occurs.

Before the blooming of the alfalfa there is a varied and abundant bloom of native plants and dandelion. Alfalfa bees in this area belonging to the genus *Megachile* should be able to find sufficient food at one plant

species or another to prevent actual starvation in any typical area in which the native bloom has been reasonably conserved. Even if the actual nesting at this time is retarded for lack of bloom nearby, this should not have much effect upon the number of bees for the following year.

About the time that the alfalfa begins to bloom, the alfalfa fields have an abundant bloom of dandelion, a plant that produces both pollen and nectar abundantly in warm weather (Lovell, 41). Dandelion was not recorded at White Fox as being visited by either *M. frigida* or *latimanus* and the visits of other, less numerous, tripping species were few (Tables 3, 4). Nevertheless, *latimanus* and *inermis* have been recorded from this plant by Mitchell (49). Dandelion may therefore be merely less attractive to these alfalfa bees than alfalfa and, if so, may play an important role in providing food during the critical feeding period before the alfalfa blooms.

The bloom of two other common plants, perennial sow thistle and fireweed, have been noted by Knowles (37) to attract *Megachile* species in alfalfa fields at White Fox. In Table 4 it is shown that, while *frigida* was rarely attracted to sow thistle, yet *latimanus*, *inermis* and *relativa* were visitors to an appreciable degree. Fireweed was quite attractive to most of the bees, although it was not close to the alfalfa and therefore not strictly in competition. While the control of both of these plants may be desirable from the viewpoint of tripping, yet these plants may be beneficial in supplying food after the first fall frost has killed the alfalfa bloom.

As cooler weather sets in during the fall, there is a diminution or cessation of nest-building by *Megachile*. An abnormally early fall frost would kill the alfalfa bloom and, if the bees survived, would make them dependent upon the native bloom, which is scarce at this time. However, available collection dates suggest that these heat-loving bees are killed or inactivated by a fall frost.

A comparison of the feeding habits of *Megachile* and *Bombus* shows that the population of the latter alone is prone to early spring starvation, while early fall frosts are also likely to reduce the population for the next year much less severely in *Megachile* than in *Bombus*.

Disease and Mould

No investigations were made upon these factors. Nests in both soil and logs have been found filled with mould and this was true also of many nests built in the drilled holes of an incompletely dried log of poplar. Mould also was found in 3 nests of sound wood (Table 5). No conclusion can be reached upon these moulds being saprophytic or parasitic, although, if saprophytic, as seems likely, the use of sound wood seems to be a logical means of reducing losses of bees in artificial nesting sites.

Parasites and Predators

Changes in the habitat and environment of an insect group are usually followed by fluctuations in the populations, not only within this primary group, but also within a secondary group formed by their parasites and predators. The densities of these two groups, their specific compositions and their inter-relationships should be of special interest in the case of the

alfalfa bees at White Fox, since these bees have been subjected to abnormally great environmental changes caused by the destruction of much of the vegetation.

The parasites and predators of bumble bees, and the inquilines of their nests, have been studied by Frison (24) in Illinois. The conopids, or large-headed flies, commonly parasitize adult bumble bees (Meijere, 45; Frison, 24) and are likely to be overlooked as a factor that reduces the efficiency of adults. Their predators include mammals, such as mice and moles (Frison, l.c.), and asilids (Bromley, 7). Frison's extensive list of inquilines has been supplemented with some lepidopterous records by Milum (47). On the other hand, although bumble bees have a long list of enemies, it is worth recording that losses in bumble bees can be slight. A nest of *B. americanorum* F. was dug up late in the season by Rau (62) and contained 138 adults and 238 immature bees; only 6 workers had been lost from the nest and there was no evidence of the presence of social or other parasites. Nesting records, taken in a similar manner at White Fox, would assist greatly in making population studies.

Adult bees of both *Bombus* and *Megachile* at White Fox were frequently carrying many hypopi of various acarid (tyroglyphid) mites. As these are merely in the dispersal stage, they do not normally inhabit the nests and, in any case, since their mouth parts are vestigial, they cannot attack either the immature or adult bee. These mites are therefore of no direct importance as parasites or predators (Michael, 46).

At White Fox both the probable crowding of alfalfa bees into restricted nesting areas and the establishment of artificial colonies in logs may favour the increase of parasites and predators. Studies upon nesting populations were confined to those nests that were built in the log colonies, rather than those in natural nests. This was done, in part, to save time in searching for nests and in handling but also, in part, to establish the identities of the colonizing bees.

The percentage of harmful inquilines in nests of artificial colonies may be affected by the size of the colony. Although a female inquiline may find nests more easily, particularly so if she herself matured in the colony, yet her use of such a nest may result in a higher loss of her progeny through other noxious inquilines that also found the nests more easily. Again, the inquiline newly emerged from a colony may lose the location of the nest by satisfying her needs such as feeding from flowers or finding a mate. The grouping of the nests may also mean that the numbers of the bees around the nests may deter inquilines from entering. The effect of the size of colony upon the inquiline population is therefore not necessarily beneficial to either bee or inquiline.

At White Fox, data were obtained upon the numbers of inquilines found in new colonies but not in any established for longer than a year. The reported proportions of inquilines may therefore be lower than if older colonies had been examined. The results, shown in Table 5, should be considered only as a preliminary study to a problem that requires intensive work for some seasons. These figures, however, suggest that colonization has not been of great advantage to the inquilines and that any increased ability to find bee nests, if present, has been neutralized by one or more factors.

Among these factors may be the deterrent effect of the continued activity to be found about a large vigorous colony during flying weather. This is in turn affected by the distance of the colony from the sources of pollen, nectar and such leaves as are suitable for building nests. At White Fox an artificial colony of *M. inermis* and *nivalis* was well established in a cedar log within 10 yards of both alfalfa and poplar (Table 5, log 2). This attracted numbers of bees of the species *Coelioxys moesta* and *C. lucrosa*, the larvae of these being predators within the cells of *Megachile* (Graenicher, 30, 31). Nevertheless, no trace of *Coelioxys* was found when the nests were dissected after rearing was completed. On the other hand, another log (Table 5, log 3) with nests of *M. nivalis* had *Coelioxys* in 5 out of 18 occupied tunnels. The numbers of *Megachile* bees in and about Log 2 may have been sufficient to ward off the *Coelioxys* attacks.

It is worth recording, at this point, that Log 2 was also attractive to cuckoo wasps (*Chrysis* sp., probably *coerulans* F.). Although no individuals of either *Chrysis* or *Coelioxys* were seen to enter the log, yet the apparent interest of the wasps suggested strongly that they also intended to use the nests. No specimens of these wasps were reared nor was other evidence seen of their being inquiline. Records from two of the monographs on the family (Mocsary, 52; Bischoff, 6) suggest that these chrysidids may have been searching for nests of another hymenopterous group, possibly *Osmia*. However, Friese (21) recorded the chrysidid genera *Holopyga* and *Hedychrum* as being reared from *Megachile*, while Dalla Torre (13) had seven palaearctic records of such chrysidid parasitism, including four for *Chrysis*. The ability of *Chrysis* to oviposit in the solitary, and the colonial, nests of *Megachile* may be worth studying.

Records of inquilines in the nests of leaf-cutter bees are scattered in the literature. Those in the works of Bezzi (5), Dalla Torre (13-15), Friese (21, 22), Gahan (29), Malloch (43), Morley (53) and Thompson (71) are listed in Table 6. Additional nearctic records were also added. Most of the records are European but it is interesting to note that the inquilines in the palaearctic and nearctic regions so frequently show similarity by occurring together in certain, widely separated genera or groups; indeed, as *M. centuncularis* is now considered as holarctic (Mitchell, 49), one may suspect that some of the inquiline species may also be holarctic.

At White Fox 156 nests were taken from artificial colonies. Unfavourable temperatures during shipping apparently caused many deaths among the larvae, so that only 63 nests produced either bees or inquilines. These are recorded in Table 5. The associations of the bee species with their inquilines are as follows:—

Megachile nivalis: Coelioxys moesta Cress., *Ichneumon* sp., *Anthrax irrogata* Say, *Physocephalus dakotensis* V.D.

Megachile inermis: Ichneumon sp., *Dibrachys* sp.

Important amongst the harmful inquilines in *Megachile* nests are species of the megachilid genus *Coelioxys*, in which the newly hatched larva kills the *Megachile* larva and then feeds upon the pollen and nectar in the nest (Graenicher, 32). *M. latimanus* and *M. melanophaea* var. *wooteni* Ckll. are both preyed upon by *C. dubitata*, while *M. frigida (vidua)* is

TABLE 6.—HOLARCTIC PARASITES AND PREDATORS IN *Megachile* NESTS[1]

Order	Family	Genus	Nearctic species
Coleoptera	Meloidae	*Meloë*	—
	Cleridae	*Trichodes*	——
Diptera	Bombyliidae	*Anthrax*	*irrogata* Say (new record)
		Spogostylum	—
	Conopidae	*Physocephalus*	*dakotensis* V.D. (new record)
	Sarcophagidae	*Miltogramma*	—
Hymenoptera	Ichneumonidae	*Spilocryptus*	sp. (33)
		Kaltenbachia	——
		**Ichneumon*	sp. (new record)
	Leucospidae	*Leucospis*	*affinis* Say (15)
	Torymidae	*Monodontomerus*	? *emarginatus* Gahan (29)
	Pteromalidae	*Dibrachys*	sp. (new record)
		**Semiotellus*	*cupraeus* Prov. (34)
	Eupelmidae	*Calosota*	——
	Eulophidae	*Melittobia*	*megachilis* Pack. (57)
	Mymaridae	**Pteratomus*	*putnamii* Pack. (57) (Hyperparasite)
	Chrysididae	*Chrysis*	——
		Stilbum	——
		Hedychrum	——
		Holopyga	——
	Sapygidae	*Sapyga*	*fulvicornis* Cress. (39)
	Megachilidae	*Stelis*	——
		Dioxys	*coloradensis* Cress. (35)
		Coelioxys	*dubitata* Sm. (32, 35, 63)
			grindeliae Ckll. (35)
			hicksi Ckll. (11)
			lucrosa Cress. (32)
			modesta Sm. (31, 64)
			moesta Cress. (new record)
			octodentata Say (20, 35)
			ribis Ckll. (31)
			rudis Ckll. (11)
			sayi Rob. (64)

[1] Compiled from the literature, and from the records of the authors for the White Fox area.
* Not recorded from the palaearctic region.

similarly attacked by *C. lucrosa* (Graenicher, 32). These two species may therefore be important factors in keeping down the population of the alfalfa bees in the genus *Megachile*. Four males and 5 females of *Coelioxys* were reared, all from the same colony (Table 5, log 3). The females run readily to *moesta* in the key by Sladen (67) and are believed to be that species. The associated males also run by this key to *moesta* except in their having small round foveae on the second tergite. The association of the forms seems as sound as one can obtain without rearing both sexes from the same mother; the failure to obtain both sexes from the same nest is of course not especially significant. The male of *moesta* has only been described as such by Sladen (*l.c.*) and therefore the correctness of his associations has not been confirmed by other workers.

Only one species of ichneumonid was reared from the nests. This belonged to the genus *Ichneumon* (*s.s.*), both males and females being reared. This species may prove to be *I. brevis* Morley but the type of this is inaccessible; otherwise the species appears to be new. The female has a long ovipositor for piercing both the individual nests and the mud

cap that seals each nest entrance. In one case 3 females were reared from the second to fourth nests in the same hole. One may judge from this and from the usual number of nests in a hole that most of the leaf-cutter nests are liable to parasitization by this species after the nest hole has been completely filled by nests.

A relatively large number of chalcids have been recorded in Table 6 as parasites of leaf-cutter bees. The potential parasitism by chalcid species is suggested by the records of Guignard (34) and Putnam (61). Guignard found every larva in a colony of 20 nests of "*M. optiva*" (apparently *melanophaea*) were parasitized by *Semiotellus cupraeus* Prov. Putnam recorded that a single nest of *M. centuncularis* contained over 150 adults of *Melittobia megachilis* (Pack.) and, according to Packard (41), these were in turn parasitized by *Pteratomus putnamii* Pack.

At White Fox the only adult chalcids reared from *Megachile* were 2 males and 23 females of *Dibrachys* reared from a single nest of *M. inermis*. Two chalcid colonies from another site contained 26 and 32 unidentified larvae. In none of these was the nest pierced by the chalcid mother.

Both the reduction in the area of possible nesting sites and the use of artificial colonies in logs are factors that tend to assist chalcids in their search for hosts, because of their relatively weak flight. Indeed, this colonization seems ideal for *Melittobia*, a genus in which the males are recorded as wingless and the females as fully winged but virtually flightless (Browne, 8; Buckell, 9).

The means by which large numbers of adult chalcids can develop from one small bee larva are of interest. The parasitizing of the egg or of the earlier larval stages would seem to tax too severely the ability of the young bee to supply food to the numerous parasitic larvae. On the other hand, later parasitizing may seem unlikely because (1) the finished nest is usually inaccessible to the chalcid and (2) an excessively long period would elapse before the bee larva would be capable of feeding the chalcid larvae and, during this time, either the mother would have to survive or her eggs lay dormant in the nest.

A clue is suggested by the life cycle of the European chalcid, *Melittobia acasta* (Wlk.), which parasitizes leaf-cutter bees, other wild bees and wasps. The following observations of Browne (8) on this species are pertinent. The adults of *M. acasta* are often found enclosed in bee cells, are able to feed on solitary young larvae without hindering the host development, and can remain as long as 50 or 60 days beside a future host before ovipositing in it. These qualities together would seem to allow this chalcid to delay oviposition until the host is sufficiently large to nourish the parasitic larvae. The bee-food stored in the nest may also be of value in lengthening the life of the mother chalcid. The feeding of adult female chalcids upon future hosts is found among other chalcids, including the nearctic species *Melittobia chalybii* Ashm. (Buckell, 9), the holarctic *Dibrachys cavus* (Wlk.) (Faure and Zolstarewsky, 19) and a number of species in various chalcidoid families (Clausen, 10). This feeding habit may therefore be used to synchronize the life cycle of *Dibrachys* and other chalcid parasites with that of its bee host.

On the other hand, there is evidence that suggests that more than one generation of parasites may be produced in a nest. According to Howard and Fiske (36), only the females of *M. acasta* are long-lived. Such females lay only 4 or 5 eggs on individual larvae of the gipsy moth, *Porthetria dispar* L. These eggs produce only males, mating then takes place with the mother and the resulting eggs produce female parasites. At White Fox the parasitized nest contained 2 males and 23 females, the males and some females being dead when first examined. These numbers are suggestive of the conditions reported by Howard and Fiske (*l.c.*) but unfortunately there is no proof that the males did not enter the nest while it was being built. Detailed observations upon the life cycle of this species of *Dibrachys* at White Fox may show the method of synchronization.

The flies reared from the nests of leaf-cutter bees at White Fox belonged to two species, *Anthrax irrogata* Say[1] in the Bombyliidae (bee-flies) and *Physocephalus dakotensis* V.D. in the *Conopidae* (large-headed flies).

Although the Bombyliidae, as a family, have exceedingly varied hosts, yet their species are confined within relatively narrow limits: the genera *Anthrax*, *Argyramoeba* and *Spogostylum* are recorded by Bezzi (5) as inquilines of *Megachile* nests. There appear to be no *Megachile* records for the nearctic area, although *A. irrogata* (as *Argyramoeba oedipus* F.) has been noted as an external parasite of solitary wasps belonging to the genus *Odynerus* by Baker (4). The 2 specimens reared at White Fox were found in the second and third cells out of a row of four.

The rearing of one adult of the conopid, *P. dakotensis*, is of unusual interest. According to Clausen (10), the members of this family usually parasitize adult hosts, although there is some evidence that larvae of *Vespa* may be attacked. In the case of the White Fox specimen, there can be no doubt that the entrance of the parasite to the nest was made before the nest was complete, since the nest was intact during the winter, the nest itself being isolated in a tin until the emergence of the adult bee host and again isolated in a Schmitt box with its pinned host and some other dead bees. The conopid pupated within the abdomen of its host, as is normal for conopids. Possibly the parasite egg was laid in the normal manner upon the mother bee and was carried as a larve into the nest. However, as the eggs of this group show no embryonic development at the time of deposition (Clausen, 10), it therefore seems likely that the adult conopid laid the egg either on or near the egg of its future host and that the larva fed upon the bee-food until the time when it parasitized the bee.

From the above discussion upon the hymenopterous and dipterous parasites of alfalfa bees, it is evident that these parasites were not of major importance in limiting the number of alfalfa bees at White Fox during 1944. Nevertheless, during other seasons the importance of their role may be greatly increased or lessened; and, as already emphasized, this may be especially true if artificial nesting sites are used to increase the numbers of bees in the fields of alfalfa.

[1] Determined by the key published by Maughan (44).

SUMMARY

In the White Fox district, as in others, an adequate setting of alfalfa seed is dependent upon the presence of sufficient numbers of bees to fertilize the alfalfa flowers by tripping and cross-pollinating.

At White Fox the important bees for tripping are leaf-cutter bees (*Megachile* spp.) and bumble bees (*Bombus* spp.). Honey bees are plentiful but unimportant except perhaps for their competition with wild bees for pollen and nectar during times of scarcity.

The burning of the brush and the ploughing of the sod by farmers have caused the destruction of many bee nests containing immature and adult bees, as well as spoiling many sites suitable for future nesting. Furthermore, this destruction has deprived the bees of many sources of nectar and pollen.

In the poplar areas *Megachile frigida* was by far the most important leaf-cutter bee for tripping during 1944. Other species were also useful, including *relativa*, *nivalis*, *inermis*, and *melanophaea*. In the sandy, jackpine areas *M. frigida* was still the most common species although *latimanus* was important also. The most valuable bumble bee was *B. terricola*, although *B. ternarius* and *B. rufocinctus* (*s.l.*) were also useful; these were found in both poplar and jackpine areas.

Suggestions are made for the restoration of nesting sites for *Bombus* and *Megachile* by a variety of ways. *Megachile* bees show strong specific preferences towards certain types of nesting sites. Bumble bees nest either in or on the earth.

The preservation of existing nesting sites and the establishment of new ones are essential for high yields of seed from well established alfalfa areas. Early nesting of bumble bees may be encouraged by placing boards 1 inch above the sod in suitable places. Artificial domiciles for bumble bees, such as those devised by Sladen and Frison, cannot be considered as practical unless supervision during the growing season can be eliminated. The alfalfa fields should be surrounded by a wide strip of uncultivated land for nesting; such areas should not be subject to flooding, to disturbance by farm machinery or to shading by heavy bush. Fence-rows and road allowances may provide nesting sites. Artificial nests, made by boring holes in logs at White Fox, have been used by *M. nivalis* and *inermis;* although the important species *frigida* has taken great interest in such nests, no specimens have been reared. The rearing of leaf-cutter bees in such colonies may affect the influence of the harmful inquilines, although such does not at present seem true. Four species of inquilines were reared.

The populations of *Bombus* spp. are probably subject to much greater fluctuations than those of *Megachile* spp. because of starvation.

Early spring bloom is needed for the *Bombus* queens emerging from hibernation. An increasing supply of bloom is then needed until the alfalfa blooms, or else the colonies will be weak during the important early blossoming of this plant. The growth of early flowering plants should be encouraged at the edges of alfalfa fields.

Megachile adults emerge about the middle of June. The flowers of dandelion and native plants probably provide sufficient food until the alfalfa blooms.

During the alfalfa bloom there is abundant food supplied also by other plants and the alfalfa bees must be restricted to alfalfa bloom as far as reasonably possible. The cutting of hay crops of flowering plants such as sweet clover and alfalfa should therefore be carried out before the seed crop blooms. The bloom of dandelion, sow thistle and fireweed is abundant at White Fox; dandelion is not a competitor and may be useful in supplying food before the alfalfa blooms; sow thistle is moderately attractive to alfalfa bees; fireweed is quite attractive to *M. frigida*, the most important species. Control of sow thistle and fireweed by any practical means is desirable.

An early frost in the fall may deprive the bumble bees and leaf-cutter bees unusually soon of their normally plentiful supplies of food from the alfalfa. Unless there are other suitable sources of food, such as goldenrods and sow thistle, the deaths among *Bombus* may be so numerous as to seriously lower the number of colonies in the next season. Such a famine would not affect the population of *Megachile* as greatly during the next year, since the young have been provisioned.

Field data are needed upon the flower visiting of various species in *Bombus* and *Megachile* during spring and August to ensure to these bees an adequate supply of food.

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APPARATUS AND TECHNIQUE FOR PHOTOGRAPHING GRAIN KERNELS AND SIMILAR OBJECTS[1]

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Photographs of grain kernels and other small objects, which are to be reproduced in scientific journals, require special equipment and technique. They are too small for ordinary cameras, and a microscope with camera attachment is unsuitable because of limitations in the depth and area of the field. Commercial equipment for low-power photography is available, but is relatively expensive. This paper describes a simple camera, built in this laboratory, for producing photographs of specimens of actual size, or magnifications up to about four diameters. Information on accessory equipment, films, developer, colour photography, and technique, is also included.

EQUIPMENT AND TECHNIQUE

Camera

A drawing and a photograph of the camera are shown in Figures 1 and 2. The body of the camera consists of a bronze cone cast from wood patterns made in the laboratory workshop. Lens and shutter were purchased and are mounted in a tube which threads into the lower end of the cone. The square threads have a lead of $\frac{1}{8}$ inch per revolution and thus provide for rapid and accurate focusing. A bakelite adapter, screwed to the top of the cone and lined with plush, takes either a ground glass focusing panel or a $2\frac{1}{4} \times 3\frac{1}{4}$ Graflex cut film holder. The camera assembly is nickel plated and, to avoid reflections, the inner surface is blackened with blackboard slating.

The choice of a lens is important because of the fine detail it must register and the many corrections involved in the manufacture. In this laboratory, micro tessar lenses are used which are corrected for spherical aberration, oblique aberration, axial chromatism, and lateral chromatism (3). These are 4 element lenses, especially designed for low power magnification, having extreme flatness of field, high speed, good image formation, and high resolving power. An f/4.5 lens with a 48 mm. focal length has been found most useful for photographing grain; it covers a field of approximately $1\frac{1}{2}'' \times 1\frac{1}{2}''$ and gives magnifications up to about 3 diameters at a lens-to-film distance of 192 mm. A second lens with a focal length of 72 mm. has also been used to obtain magnifications of lower diameters. For some work requiring greater magnification, say up to about 10 diameters, lenses of a focal length of 16 or 32 mm. may be required. A shorter focal length lens gives greater magnification at equal lens-to-film distances.

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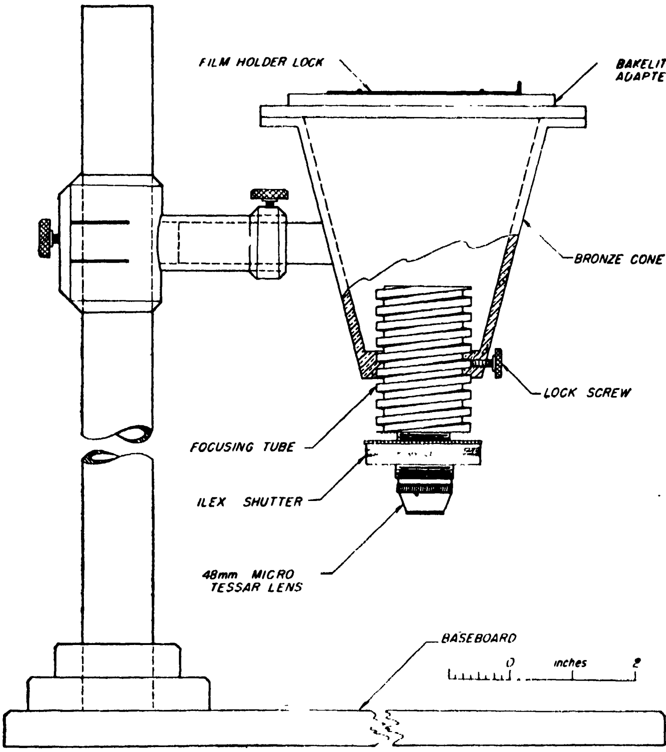

FIGURE 1. Drawing of Camera.

The camera has an Ilex Number 00 shutter with time, bulb, and speeds ranging from 1 second to 1/300 second.

A suitable stand for the camera is also shown in Figures 1 and 2. It provides means for raising or lowering the camera and for tilting it to any desired angle.

Lighting

The detail in the photographs can be increased considerably by correct lighting. For the barley kernels shown in Figure 3 and for other specimens not requiring instantaneous shutter speeds, good results have been obtained with two 15-watt Cenco Universal microscope lamps. These occupy a minimum space and are easily adjusted for height and angle. The insect illustrated in Figure 4 is black and the only way to obtain variations in tone is to adjust the lighting correctly. To show up detail and bring up highlights, the angle of illumination should be about 20°, but this will vary considerably with the type of stage and the amount of detail to be shown. The artistic sense of the photographer is of first importance in this connection. A ground glass focusing panel is a great help in assessing the lighting, and it may be added that better results than those observed on the ground glass are rarely obtained in the finished photograph.

FIGURE 2. Photograph of Camera and Cenco Microscope Lamps.

If instantaneous shutter speeds are necessary, more concentrated and intense lighting is required. The photograph of live insects shown in Figure 5 was taken at a shutter speed of 1/100 second employing 3 number 1 photo-floods and a 150-watt reflector spot lamp for illumination. Control of lighting under these conditions is quite difficult. However, if powerful microscopic spot lamps and projection lamps are availabe many of these difficulties are minimized.

Film

Tri-X panchromatic film has been used for most of the work in this laboratory. It has an emulsion speed of 100 Weston rating, which makes it suitable for rapid shutter speeds. Ortho-X is also satisfactory and gives slightly higher contrasts. As a wider range of films becomes readily available, it may well be found that films of slower speed and finer grain are better for certain types of work.

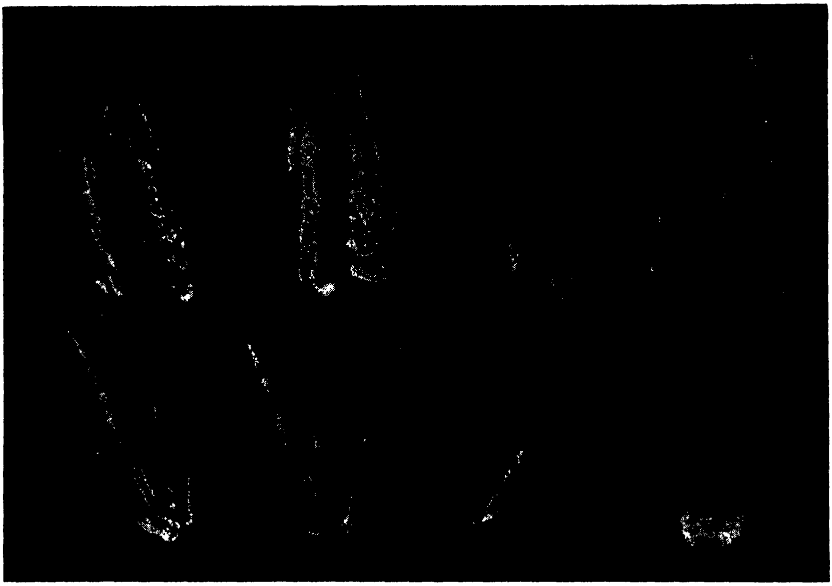

FIGURE 3. Photograph of barley kernels showing detail obtained with the correct lighting, and using Edwal Super-20 for developing the films.

Exposure

Experience in this laboratory suggests that the exposure time for black and white film is best determined by trial and error, as an exposure meter is difficult to use for close-up work. However, if conditions warrant the use of an exposure meter, it will be necessary to calculate the effective f value, which is decreased because the object is closer than eight times the focal length of the lens (4). The calculation may be made with the following formula (4):

$$\text{Effective f value} = \frac{\text{Indicated f value} \times \text{distance from lens to film}}{\text{Focal length of lens}}$$

Employing the two 15-watt Cenco microscope lamps and an indicated lens stop of f/16, exposure times of the order of 5 to 10 seconds have proved most satisfactory for grain kernels and similar objects.

Developer

A developer which gives clean highlights and fine detail in the deepest shadows is required. Satisfactory results have been obtained with Edwal Super-20 fine grain developer (6) using 37 minutes developing time at a temperature of 70° F. Tests conducted at a wide range of exposure times indicated that this developer has considerable tolerance to variations in exposure. A modified DK-20 developer (2) has also been used. The developing time is shorter (16 min. at 70° F.) but the developer has less exposure tolerance and thus demands greater care in obtaining the correct time.

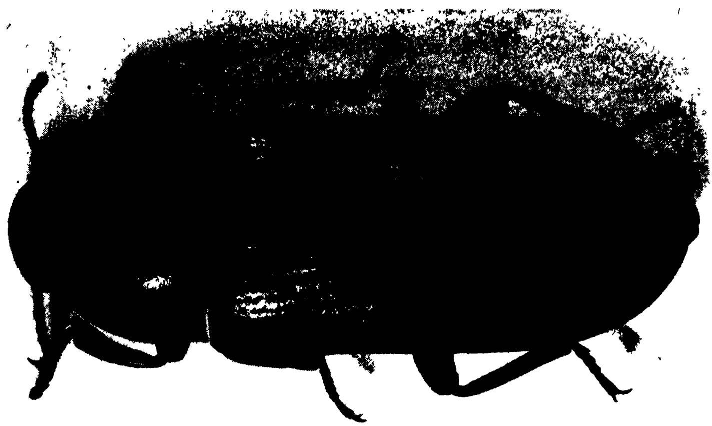

FIGURE 4. Yellow meal worm adult showing what can be done with suitable lighting.

Enlarging

As the engraver will prefer a larger photograph than is to be reproduced in the journal when making his cut, it is frequently necessary to make an enlargement unless a large camera and complete stock of lenses at various focal lengths are available. A condenser type enlarger fitted with a 72 mm. micro tessar lens is used in this laboratory. In most cases prints are made on Number 4 Glossy Kodabromide paper. Two developers, Edwal-102 (6) and Kodak D-72, have been used, and the results showed little difference between them. The developing time of Kodabromide paper in D-72 at 70° F. is from 1 minute to about 1½ minutes as compared with 2½ minutes to about 5 minutes with Edwal-102. The D-72 developer was chosen because of its shorter developing time.

FIGURE 5. Live Granary weevils photographed at instantaneous shutter speeds.

Reproduction

The quality of paper that the cuts will be printed on is the determining factor for the type of cut to be made, and for the best results the advice of the photo engraver and the printer is invaluable. Illustrations of grain kernels must reproduce a high degree of detail. For those shown in Figure 3, a 150-line copper screen half-tone cut was made and printed on good quality dull enamel paper.

Colour Photography

The equipment described has been used for colour photography, and some examples have been published elsewhere (5). Kodachrome professional type B film, having a colour temperature rating of 3200° K. (1, 4) and a film speed of 6 Weston units, was used. No. 1 photoflood lamps rated at a colour temperature of 3490° K. were employed for illumination. The truest colour rendition is obtained when the colour temperature of the lamps is 3200° K. However, a deviation of about 50° K. will give good transparencies. To obtain illumination of 3200° K. with the photofloods, the line voltage was reduced to 90 volts. The rule is that for a drop of 1 volt in the line, the colour temperature is reduced by approximately 10° K. Suitable filters are also available for increasing and decreasing the colour temperature of lamps, and a colour temperature meter is invaluable for determination of temperature.

Kodachrome has a very limited exposure latitude, and the exposure time must therefore be accurate. Moreover, as Kodachrome must be sent to the factory for developing, a test exposure cannot be made without considerable delay and expense. The Eastman Kodak Company recommend (4) that this difficulty be overcome by making a series of test exposures on Kodak Super-speed Direct Positive Paper. This is available in sheets or in film sizes, and processing instructions are enclosed with it. An alternate method, which has been used in this laboratory, is to make the test exposures on a black and white film with speed and exposure latitude closely similar to those of Kodachrome. Kodak 35 mm. Direct Positive movie film, developed in D-72 (1 part stock solution to 2 parts water) for five minutes at 70° F., is very satisfactory. Experience suggests that conditions equivalent to slight underexposure of the movie film give the best results with Kodachrome. However, in making the fine adjustments required to obtain the best transparency, individual judgment and preference play so large a part that specific advice can hardly be offered.

SUMMARY

Apparatus and technique are described for photographing grain kernels, insects, and other specimens of similar size. The camera consists of a cast bronze cone with a lens mounted in a threaded tube for focusing on a ground glass. Good photographs of kernels and insects were obtained with Tri-X Panchromatic film developed in Edwal Super-20 developer. Correct lighting is important to obtain detail and variations in tone. For colour photography, colour temperature of the lamps and exposure time must be determined accurately.

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MAXIMUM DEPTH OF SEEDING EIGHT CULTIVATED GRASSES[1]

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Seeding perennial forage crops at too great a depth is considered to be the principal cause of failure to secure satisfactory stands within the plains region of Western Canada. However, under these arid conditions, the deeper that seeds can be placed the better soil moisture may be for germination. Therefore, a desirable characteristic of any new species or variety would be ability to emerge from greater depths than commonly grown species or varieties. In addition, rapid rate of emergence also would be desirable, enabling plants to become well established while climatic conditions were favourable.

Recently, several relatively new grasses have shown promise of being suitable for much of this area. In an effort to supply data on agronomic characteristics a greenhouse experiment was conducted in 1946 to determine the maximum depth at which 4 of these grasses may be seeded and still obtain satisfactory emergence. Included in the experiment were 4 other standard grasses. This paper summarizes the results of the experiment.

LITERATURE

Love and Hanson (5) obtained good emergence of crested wheat-grass at a ¾-inch depth of seeding on clay soil but at greater depths, emergence fell off sharply. Similar results are reported by Kirk, Stevenson, and Clarke (4).

Murphy and Arny (6) concluded, from field and greenhouse experiments, that depth of seeding was the most important factor governing seedling emergence. A ½-inch depth was most satisfactory for the 10 crops studied on various soil types, although brome and Reed Canary grass gave satisfactory stands from greater depths. There were differences in the per cent emergence of the crops on different soil types. Environmental conditions influenced emergence considerably.

Clarke and Heinrichs (2) and Heinrichs (3) recommend shallow seeding for crested wheat-grass and sweet clover, not over 1 inch on clay soils and not over 1½ inches on sandy soils. Greenhouse experiments showed that better emergence of seedlings resulted on sandy loam soil than on clay loam at given depths. Although no brome seedlings came up when seeded 3 inches deep in clay loam soil, 53% emerged on sandy loam at this depth. Greater emergence resulted when the surface soil was dry than when it was moist.

Wasser and Nelson (7) state that satisfactory emergence of intermediate wheat-grass is obtained by seeding from ½ to 1½ inches deep and of Russian wild-rye grass from ½ to 1 inches.

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[2] Assistants in Forage Crops.

MATERIALS AND METHOD

The following grasses were included in the experiment:

Agropyron cristatum (L.) Gaertn.	Fairway crested wheat-grass
Agropyron trachycaulum (Link.) Malte var. *typicum* Fern.	Grazier slender wheat-grass
Agropyron elongatum (Host) Beauv.	Tall wheat-grass
Agropyron intermedium (Host) Beauv.	Ree intermediate wheat-grass
Phalaris arundinacea L.	Reed Canary grass
Bromus inermis Leyss.	Parkland brome
Elymus junceus Fisch.	Russian wild-rye
Elymus virginicus L. var. *submuticus* Hook.	Virginia wild-rye

Before seeding, germination tests were made on all seed lots. Adjustments in the amount of seed sown were made so that 100 theoretically viable seeds were sown in each plot. Haverhill loam soil, which had been air dried and sieved to remove lumps, was used for the experiment. Seeding was done in flats measuring 14 by 16 inches and 4 inches deep.

The grasses were sown at 6 depths, ½ inch, 1 inch, 1½ inches, 2 inches, 2½ inches and 3 inches. Each flat contained 6 plots of 2 rows each. One species was sown in each flat. This was accomplished by constructing wooden soil levellers of the required depths and planting the seed at the 6 depths consecutively, starting with the 3-inch depth. Six replicates

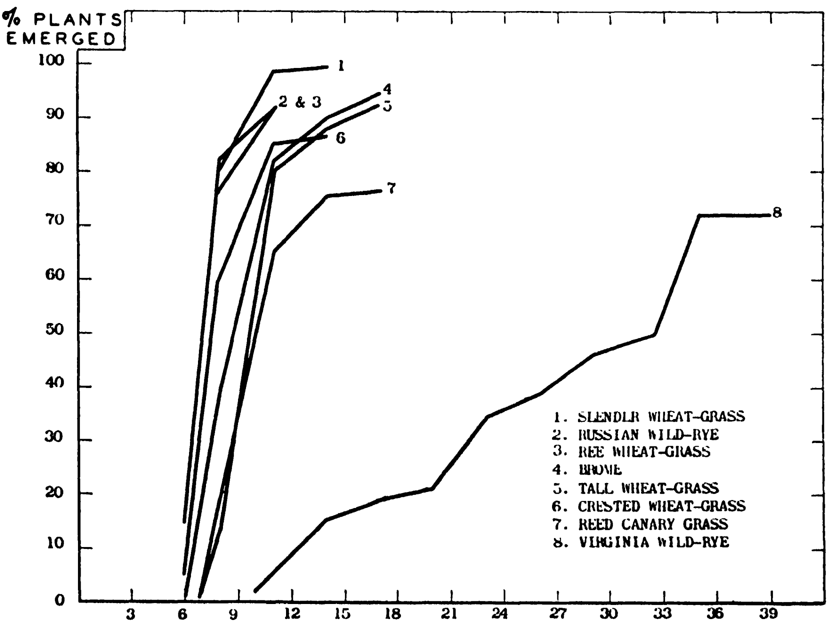

FIGURE 1. Rate of emergence of 8 grasses from ½-inch depth.

were used, a replicate consisting of the 8 grasses each seeded at the 6 depths. The various depths of seeding were randomized within each flat and the flats were randomized within each replicate for position in the greenhouse.

Following seeding the soil was moistened thoroughly and kept at optimum moisture for the duration of the experiment. Notes were recorded daily on the number of days required for the emergence of plants from each depth. Total emergence counts were made every 3 days on all the plots. The experiment was terminated 39 days after seeding at which time all grasses, with the exception of Virginia wild-rye, had ceased to show any increase in total emergence.

RESULTS

Rate of Emergence

The rates of emergence of the 8 grasses from the ½-inch depth (the optimum or near optimum depth for most of the species) are shown graphically in Figure 1. Five of the grasses began emerging 6 days after seeding while tall wheat-grass and Reed Canary grass emerged 1 day later and Virginia wild-rye 4 days later. Ree wheat-grass and Russian wild-rye were the first to complete emergence from the ½-inch depth, 9 days after planting, followed by slender wheat-grass, crested wheat-grass, tall wheat-grass, brome and Reed Canary grass, the latter reaching maximum emergence 14 to 17 days after planting. The rate of emergence of Virginia wild-rye was very slow and was not complete at the end of the experiment.

The rate of emergence of each species from the various depths is shown in Figure 2. In general there is a lag of one day between depths but this increases with the greater depths. Emergence was complete from all depths in 20 days for crested wheat-grass and Russian wild-rye; in 23 days for Ree wheat-grass; in 26 days for tall wheat-grass, slender wheat-grass and brome; and in 29 days for Reed Canary grass. Virginia wild-rye had not completely emerged 39 days after planting.

The slow rate of emergence of Virginia wild-rye appeared to be related to some extent to the greenhouse temperature which varied from 65 to 90° F. between night and day. There was also variation in temperature in different parts of the greenhouse. In the cooler end very poor emergence was obtained from all depths while at the warmer end there was good emergence from all depths up to 2 inches. It would seem that this grass requires a higher temperature to induce germination than others in the experiment.

Total Emergence

The experiment was designed so that individual analysis of the data for each grass could be made as well as a complete analysis of the experiment. Both procedures were followed. The data on total emergence are presented in Table 1 as well as the transformed data according to the formula $P = \mathrm{Sin}^2\,\theta$ (1). The minimum significant difference given for each crop applies only to the transformed data as does the minimum significant difference for the whole experiment. Because the emergence of Virginia wild-rye was not complete, it was analyzed by itself only.

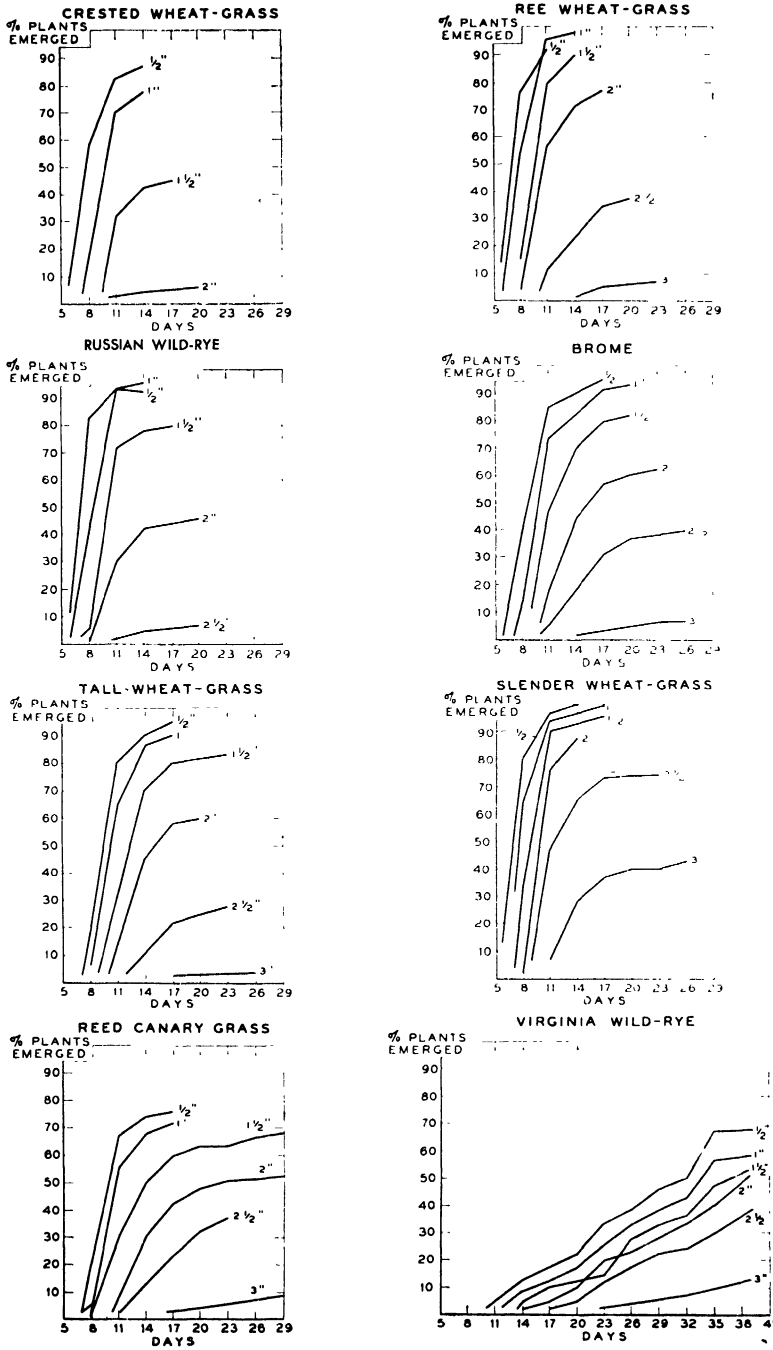

FIGURE 2. Rate of emergence of the 8 grasses when seeded at different depths (½, 1, 1½, 2, 2½, and 3 inches).

TABLE 1.—TOTAL EMERGENCE OF 8 GRASSES FROM 6 DEPTHS OF SEEDING

Species	Average % emergence from different depths in ins.						Average of data converted to sin² θ						Significant difference
	½	1	1½	2	2½	3	½	1	1½	2	2½	3	
Virginia wild-rye	66	58	53	50	39	11	56 9	49 9	46.5	44.1	37.0	14.4	11.4
Crested wheat-grass	87	79	44	6	0	0	69.6	63.6	41.6	12.6	0	0	5.98
Slender wheat-grass	99	99	97	89	74	41	87.4	86 7	83.2	72.9	59.6	40.1	6.66
Tall wheat-grass	93	90	83	61	27	3	75.8	72.6	66 4	51.6	31.0	8.9	7.47
Ree wheat-grass	92	98	90	77	38	6	75.7	86.3	71.4	61.4	37.9	13.2	8.43
Brome	94	94	83	62	40	8	76 9	76.4	65.6	51.9	38.7	13.5	8.97
Reed Canary grass	76	73	67	54	37	9	60.8	58.7	54.8	47.1	37.4	15.3	6 35
Russian wild-rye	93	94	80	46	8	0	76.8	77.2	64.1	42.5	15.7	1.4	5.67

Minimum significant difference for entire experiment (7 species) = 7.11

The F values obtained in the analyses of the data were highly significant for depths, species and the interaction of depths and species. The standard error of the experiment was 4.94%.

The total emergence of all species from the various depths at the end of the experiment is shown graphically in Figure 3.

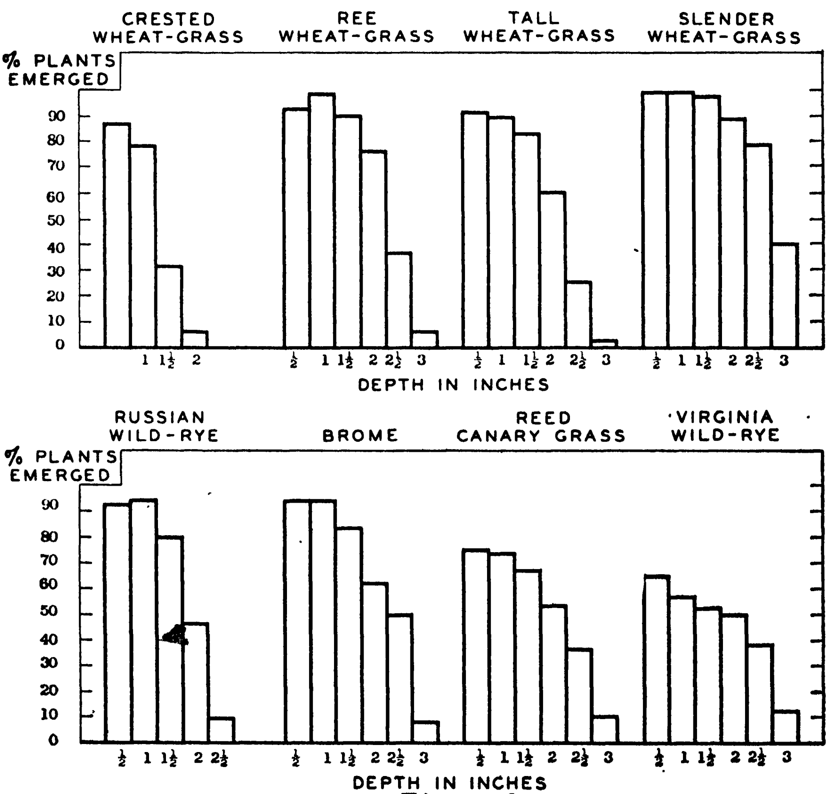

FIGURE 3. Total emergence of 8 grasses from 6 different depths. (Virginia wildrye still increasing 39 days after planting).

DISCUSSION

The data indicate that under the conditions of this experiment the maximum depth at which the species studied may be sown on loam soil is as follows:

Crested wheat-grass	1 inch
Russian wild-rye	1½ inches
Brome	1½ inches
Tall wheat-grass	1½ inches
Ree wheat-grass	2 inches
Reed Canary grass	2 inches
Virginia wild-rye	2 inches
Slender wheat-grass	2½ inches

It may be stated further that tall wheat-grass, Ree wheat-grass, Russian wild-rye and Virginia wild-rye can be seeded deeper than crested wheat-grass and as deep or deeper than brome. This is a favourable factor when establishing stands within low rainfall regions. However, the slow rate of emergence of Virginia wild-rye is a distinct disadvantage.

It is of interest to note the good emergence of Reed Canary grass, a small seeded grass, from the 2-inch depth and that of slender wheat-grass from a 2½-inch depth.

SUMMARY

A greenhouse experiment was conducted on maximum seeding depth with 4 promising grasses, Russian wild-rye, Virginia wild-rye, tall wheat-grass and Ree wheat-grass in comparison with 4 standard grasses, crested wheat-grass, slender wheat-grass, brome and Reed Canary grass. All species, with the exception of Virginia wild-rye, emerged rapidly from the optimum depth of ½ inch and emergence was complete in from 9 to 17 days after seeding. The total emergence of the eight species from the 6 depths of seeding (½, 1, 1½, 2, 2½ and 3 inches) on Haverhill loam soil indicated that the maximum depth at which the 4 new species could be seeded was greater than that for crested wheat-grass (1 inch) and equal or greater than for brome (1½ inches). The slow rate of emergence of Virginia wild-rye would discriminate against it as a suitable grass for low rainfall areas but Russian wild-rye, Ree wheat-grass and tall wheat-grass appear to be equal or superior to standard grasses in this respect.

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FEEDING TRIALS WITH CHICKS OF A NEW VITAMIN A AND D CARRIER FOR POULTRY[1]

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One of the operations most unpopular with the manufacturers of poultry and swine feeds is the handling and mixing of the vitamin-bearing oils, which constitute the only non-solid ingredient of most formulae. The destruction in mixed feeds of the vitamins, particularly A, from the common oil sources is a rather serious problem.

There are available a number of solid preparations supplying vitamin D, but few, if any, solid carriers of both vitamins A and D have been available in Canada. In view of the impossibility of depending upon yellow corn and sun-cured or dehydrated green feeds for the vitamin A activity in Canadian poultry feeds, supplementary sources of vitamin A are essential for such rations.

Recently, a solid carrier of both vitamins has become available. This product, referred to hereinafter as "A and D meal," of Canadian origin[4] is described as a "preparation of vitamins A and D in Dry Herring Meal Base." An advantage claimed for it, in addition to greater convenience in handling and mixing, is a greater stability of the vitamin content, particularly after mixing with rations, than is found with the customary oil sources of these vitamins. This is achieved by the use of stabilizing agents in the product. Tests of this material in rations for starting and growing chicks were conducted on a practical basis, in an attempt to evaluate the acceptability of the product for such rations.

EXPERIMENT 1

The first test was planned as an evaluation on a practical basis of the acceptability of "A and D Meal" as a substitute for a feeding oil in a ration for growing chicks, judged chiefly on the basis of growth.

EXPERIMENTAL

Eight groups of 36 newly-hatched Barred Plymouth Rock chicks with uniform sex distribution were placed in similar compartments of electrically-heated battery brooders maintained in the air-conditioned biological laboratory. At the end of 5 weeks, the birds were moved to growing batteries in the same laboratory, and were maintained in these until they reached an age of 10 weeks, at which time the experiment was concluded. Feed and water were before the birds at all times.

The birds in Groups 1 to 4 received Ration No. 1, and those in Groups 5 to 8 received Ration No. 2. The composition of these rations is shown in Table 1. It will be noted that the two rations were identical except for the supplementary sources of vitamins A and D. In Ration No. 1, these

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vitamins were supplied by 0.15% of a poultry feeding oil guaranteed to contain 400 A. O. A. C. units of vitamin D and 3000 International units of vitamin A per gram. In Ration No. 2, the same amounts of vitamins A and D were furnished by 0.30% of the "A and D Meal," which was guaranteed to contain 200 A. O. A. C. units of vitamin D and 1500 International units of vitamin A per gram. The amounts of these vitamins supplied in the two rations are somewhat less than commonly recommended for inclusion in practical rations although they are slightly in excess of published allowances. The purpose in avoiding any great over-supply or margin of safety in these rations was to avoid masking any practical loss or inadequacy in either vitamin supplement.

TABLE 1

Ingredient	Weight (pounds)	
	Ration No. 1	Ration No. 2
Ground yellow corn	10.0	10.0
Ground barley	14.35	14.2
Wheat bran	10.0	10.0
Wheat shorts	10.0	10.0
Ground wheat	12.0	12.0
Ground whole oats	10.0	10.0
Rolled oat groats	10.0	10.0
Dehydrated alfalfa	2.0	2.0
Cereal grass	1.0	1.0
Soybean oil meal	7.5	7.5
Meat meal	3.0	3.0
Fish meal	5.0	5.0
Buttermilk powder	1.25	1.25
Oyster shell	2.25	2.25
Insoluble grit	1.0	1.0
Iodized salt	0.5	0.5
"A and D Meal"*	—	0.3
Fortified fish oil**	0.15	—
Total	100.0	100.0
Protein (%)	19.3	19.4
Calcium (%)	1.7	1.7
Phosphorus (%)	0.8	0.8

* 1500*A*, 200D. ** 3000A, 400D.

To each ration was added:

Crystalline riboflavin at the rate of 1.28 grams per ton.

Manganous sulphate ($MnSO_4 \cdot 4H_2O$) at a rate of 4 ounces per ton.

In addition to the grit contained in the ration insoluble grit was supplied *ad libitum* to all chicks from the age of five weeks.

These rations were mixed in 500 pound lots at frequent intervals throughout the experimental period. Of each lot, one-half was fed and the other half stored for use in the stability test (Experiment 2).

All birds were weighed at the end of 4, 6, 8 and 10 weeks. In addition, records were kept of mortality and the incidence of any abnormalities, and the birds were observed for feathering and general appearance.

The birds were sexed again at the end of 10 weeks to correct any errors in the initial sex records.

Results

The weight and mortality records are summarized in Table 2.

Application of the conventional methods of variance analysis to the weight data revealed no significant differences in weight attributable to diet at any of the weighings. Mortality was quite low on both rations and there was no apparent ration effect in the few cases of perosis, the only abnormality which was noted in any of the birds. No differences in feathering or general appearance of the birds could be detected.

It is concluded that, with the type of ration used, the "A and D Meal" was a quite satisfactory substitute for the vitamin-bearing poultry oil for chicks up to 10 weeks of age as judged by weight, feathering and general appearance of the birds.

TABLE 2.—WEIGHT AND MORTALITY DATA, EXPERIMENT 1

Ration No.	Group No.	Orig. No. each sex		Average weight (grams) 4 weeks	6 weeks	8 weeks	10 weeks	Total* mortality (all causes)	Lbs. feed per lb. gain
1	1	M	15	188	370	672	1097	1	
		F	21	213	397	670	994		
(Fortified fish oil)	2	M	18	219	417	722	1138	1	4.37
		F	18	224	421	696	1032		
	3	M	20	206	401	698	1087	3	
		F	16	242	447	711	1043		
	4	M	17	213	416	716	1114	2	
		F	19	227	407	690	1023		
2	5	M	17	209	415	724	1150	2	4.56
		F	19	222	420	693	1025		
("A and D Meal")	6	M	16	202	406	727	1177	4	
		F	20	219	409	695	1020		
	7	M	16	199	406	743	1143	3	
		F	20	233	433	709	1055		
	8	M	16	209	403	721	1188	3	
		F	20	214	390	657	1014		

* Includes those birds which, having developed severe perosis, were destroyed at 8 weeks. This involved 4 birds on Ration 1 and 5 birds on Ration 2.

Experiment 2

This experiment was designed to compare the ability of two chick rations, one containing vitamins A and D in the form of a fortified fish oil and the other containing "A and D Meal," to support growth in chicks after storage under practical conditions. In addition a further test of the aspect studied in Experiment 1 was included.

Experimental

Sixteen groups of 37 newly-hatched Barred Plymouth Rock chicks were placed in pens of electrically-heated battery brooders. Sex distribution was uniform throughout the groups. The pens, management, and general routine of the experiment were similar to those in Experiment 1.

Four different rations were fed. The birds in Groups 1 to 4 received Ration No. 1 (old), those in Groups 5 to 8 received Ration No. 2 (old), those in Groups 9 to 12 received Ration No. 1 (new) and those in Groups 13 to 16 received Ration No. 2 (new).

The two "old" rations were stored portions of the complete rations mixed during the period of Experiment 1, Ration No. 1 containing fortified fish oil and Ration No. 2 containing "A and D Meal." These rations had been stored at the normal room temperature of an unheated and uninsulated storage building for a period of approximately 7 months. The period of storage for the earliest-mixed lot was from July to February and for the latest-mixed lot from September to April. In order that the storage periods might be approximately the same for all lots of the "old" rations, the various lots were fed in the order in which they had been prepared.

The two "new" rations were mixed as required during the experimental period, the composition of the two rations being identical with that of the "old" Ration Nos. 1 and 2, respectively. The 200D, 1500A "A and D Meal" used in the "new" Ration No. 2 was of recent preparation.

All birds were weighed at the end of 4, 7, and 10 weeks, and judged as before.

Results

The weight and mortality data are presented in Table 3.

TABLE 3.—WEIGHT AND MORTALITY DATA, EXPERIMENT 2

Ration No.	Group No.	Orig. No. each sex		Average weight (grams) 4 weeks	7 weeks	10 weeks	Total mortality* (all causes)	Lbs. feed per lb. gain
1	1	M	22	279	648	1221	2	
		F	15	258	542	913		
Old (fish oil)	2	M	22	268	646	1231	5	
		F	15	263	556	913		3.2
	3	M	20	252	626	1248	2	
		F	17	265	566	1037		
	4	M	19	248	602	1234	4	
		F	18	239	528	1010		
2	5	M	18	265	618	1186	2	
		F	19	257	528	969		
Old ("A and D Meal")	6	M	12	283	681	1255	2	3.7
		F	25	262	583	1046		
	7	M	16	272	634	1206	1	
		F	21	234	541	1019		
	8	M	16	311	645	1284	3	
		F	21	235	558	1071		
1	9	M	14	311	723	1301	2	
		F	23	286	606	1068		
New (fish oil)	10	M	21	289	694	1282	3	3.6
		F	16	272	616	1073		
	11	M	15	304	720	1267	2	
		F	22	276	609	1035		
	12	M	19	314	694	1271	0	
		F	18	289	611	1090		

* Includes those birds which were destroyed following the development of severe perosis. This involved 2 birds on "old" Ration 2, 1 bird on "new" Ration 1, and 2 birds on "new" Ration 2.

TABLE 3.—WEIGHT AND MORTALITY DATA, EXPERIMENT 2—*Concluded*

Ration No.	Group No.	Orig. No. each sex		Average weight (grams)			Total mortality* (all causes)	Lbs. feed per lb. gain
				4 weeks	7 weeks	10 weeks		
2	13	M	17	300	740	1323	2	
		F	20	266	579	1006		
New ("A and D Meal")	14	M	19	311	712	1305	3	
		F	18	272	595	1070		3.6
	15	M	21	294	681	1272	1	
		F	16	262	589	1074		
	16	M	20	312	720	1272	2	
		F	17	301	682	1117		

* Includes those birds which were destroyed following the development of seeere perosis. This involved 2 birds on "old" Ration 2, 1 bird on "new" Ration 1, and 2 birds on "new" Ration 2.

The results indicate that there was no appreciable difference between the groups fed the two "new" rations, nor between the groups fed the two "old" rations. Variance analysis of the weight data revealed no significant differences between the weights resulting from the two "new" rations or between the weights of birds receiving the two "old" rations. No differences in feathering or appearance of the birds were apparent, and no marked ration influence is evident in the mortality data.

It is concluded that Ration Nos. 1 and 2 underwent storage equally well as judged by the growth of chicks to 10 weeks.

It will be noted that the weights of birds receiving the "old" rations were lower throughout than those of birds fed the "new" rations. These differences in weight were found to be highly significant at 4 and 7 weeks, but not significant at 10 weeks. Whether any particular importance can be attached to this last observation it is impossible to say. In this connection it is interesting to note that the feed consumption was lower on both the "old" rations, particularly "old" Ration No. 1. Only in the latter did the feed: gain ratio differ from that on the "new" rations, but it is impossible to say whether this slight difference is of significance.

The observation that weight gains were less on the stored rations than on freshly-mixed rations is a common one. The present study gives no indication as to which factor or factors in the ration may be associated with the decreased efficacy of the ration.

Further studies to compare calcification in chicks receiving the two types of supplement are contemplated.

SUMMARY

Two experiments, in which, the weight of chicks to 10 weeks of age has been used as the chief criterion, have been conducted to compare the value in a practical ration of a new source of "vitamins A and D in Dry Herring Meal Base" with that of a conventional fortified fish liver oil. Under the conditions of the experiment, the new product was found to be a satisfactory substitute for the oil.

In a test of mixed rations containing the different sources of vitamins A and D the weights of chicks up to 10 weeks of age indicated no practical differences in stability of the vitamins from the two sources.

ACKNOWLEDGMENTS

The authors acknowledge the generosity of Harrisons and Crosfield (Canada), Limited, in making available the supplies of the new product and in providing a grant to defray part of the expenses of the experiments.

THE RESISTANCE OF WHEAT VARIETIES TO SEED BLEACHING[1]

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INTRODUCTION

The bleaching or weathering of ripe grain, standing uncut in the field awaiting the combine, or harvested grain in the swath or stook awaiting the combine or separator, results in lowered grades and economic loss to the grower. These losses are most frequent and severe in areas subject to spells of wet harvest weather. Furthermore, some varieties are known to bleach or weather much more readily than others.

Since a variety which retains its seed color is of more commercial value than one which does not, other properties being equal, an investigation was carried on in 1944 and 1945 to determine the degree of resistance to seed bleaching of wheat varieties and hybrid lines at University Farm, Saskatoon.

LITERATURE

The literature on seed bleaching of wheat is not extensive and is particularly deficient as to tests of difference between varieties.

Whitcomb and Johnson (1) investigated the effects of severe weathering on wheat and found no severe disturbance of the quality of the grain. Bracken and Bailey (2) studied the effect of delayed harvesting on the quality of wheat. They concluded that "dark, hard wheat of the Turkey Red type does not deteriorate in quality upon standing uncut in the field when subjected to alternate wetting and drying in spite of the fact that the grains bleach and lose weight per measured volume." Jewell and Miller (3) in Australia concluded that, apart from lowered bushel weight and bleached appearance, exposure of ripe grain in the ear to heavy rain followed by drying before harvest has no appreciable deleterious effect on the flour yield and baking qualities. Cayzar (4) found that light bleaching had no noticeable effect upon the milling or baking quality of Australian wheats but that severe bleaching actually tended to improve the milling and baking qualities of hard wheats, the degree of improvement depending upon the variety. Atkinson (5) found that bleached wheat had a lower bushel weight on account of an increase in volume due to the alternate wetting and drying. Copp (6) exposed 6 lines of wheat, under field conditions to artificial and natural rainfall alternated with fair drying conditions, for a period of 3 weeks. This heavy weathering did not result in any significant losses in grain weight or yield.

MATERIALS AND METHODS

In 1944 head samples were taken from every plot of the replicated yield tests of spring wheat varieties and purified hybrid lines at University Farm, Saskatoon. Similar samples were taken in 1945 from varieties and

[1] Mr. Gilmer's work on this study was made possible by a scholarship awarded to him by the Government of the Province of Saskatchewan.

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lines which had been grown in the nursery in 1944 and again in 1945, thus permitting a 2 year study of the same varieties. Each sample was taken from a border row of each plot immediately upon its' maturity and divided into 2 lots, designated as I and II, of approximately 22 heads per lot.

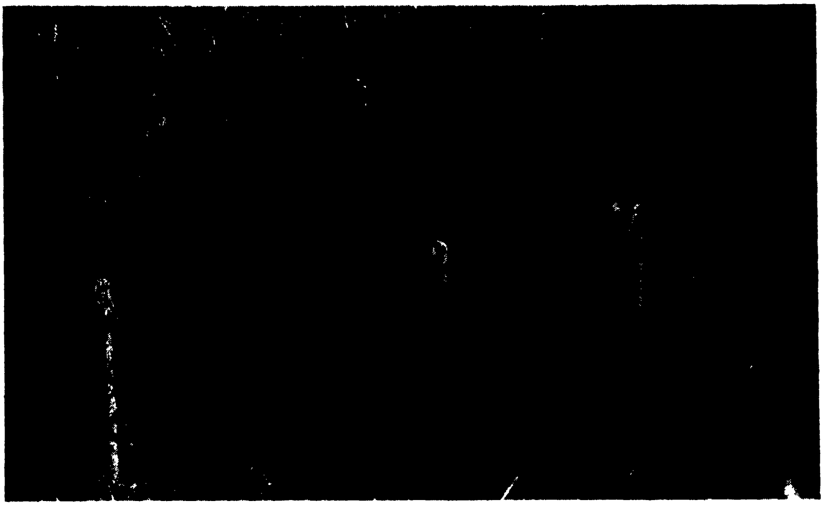

FIGURE 1. Lot I head samples from individual plots being exposed to the weather after the removal of the paper covering.

Each unthreshed sample of Lot I was wrapped in brown paper to protect it from the weather and tied to a stake, driven into the ground at the plot location as shown in Figure 1. Two days after the last plot of each particular test had ripened the paper was removed, thus exposing all the samples in each test to the same set of weather conditions at the same time. This provided a uniform test of both early and late maturing varieties. Three days after the Lot I heads were exposed to the weather one-quarter of them were taken into the laboratory where they were threshed and scored for seed color. Similar samples were taken and scored 10, 17 and 24 days after the start of exposure.

The Lot II samples were exposed to the weather as threshed grain. Before exposure each sample was divided into 3 parts, known as A, B, and C. The A samples were exposed to the weather on wooden trays in the field, the trays being protected from birds and gophers by means of a wire cage as shown in Figure 2. An estimate of the color of each sample was made on the 1, 2, 3, 6, 10, 15 and 20 day of exposure. The B samples of Lot II were exposed and scored in a similar manner as soon as the scoring of the A samples was completed. The C samples of Lot II were reserved for a bleaching test using a laboratory method.

In addition to the foregoing material a further set of samples, known as Lot III was taken 2 weeks after the last plot of each test had ripened. These samples were threshed and scored for seed color in the laboratory.

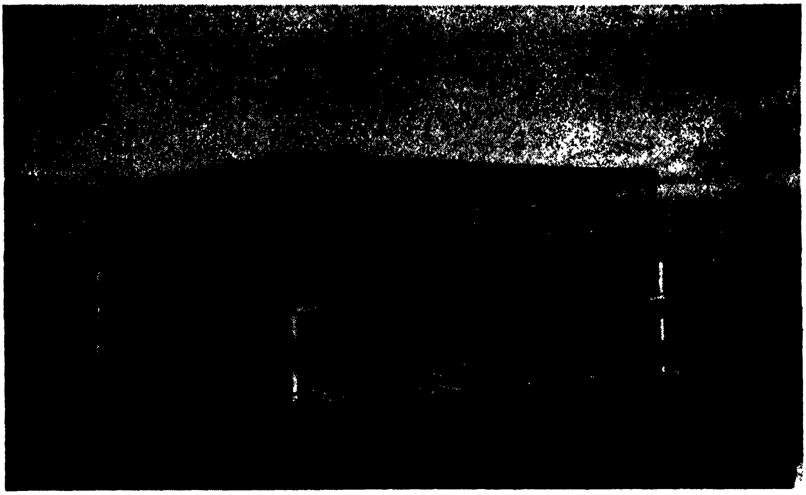

FIGURE 2. Wire cage used to protect the samples of Lot IIA and Lot IIB from birds and gophers.

All scoring was done by visually estimating the color score of each sample using as a guide both weathered and unweathered samples of standard wheat varieties. All varieties and lines used were also scored for color at maturity prior to being exposed to the weather. A variety was considered to be mature when the kernels could be indented with difficulty by the thumbnail. A record of the precipitation, temperature (minimum and maximum), hours of sunshine and wind velocity was kept for each day that the varieties were exposed.

Comprehensive laboratory tests were made to simulate the effects produced by natural weathering of unthreshed heads. Five groups of tests on 10 varieties and lines were made as follows: (A) The 10 samples were immersed in tap water at 55° F. in petri dishes for 10 minutes and then dried in a forage dryer operated at 84° F. The procedure was then repeated on fresh samples of the 10 varieties using drying temperatures of 175° F., 200° F. and 270° F. The drying time required was approximately 30 minutes. The samples were scored for color immediately after treatment. (B) Three sets of samples were immersed in tap water at 55° F. for periods of 10, 30 and 75 minutes, respectively, then dried at 200° F. in the forage dryer and scored for color. (C) Four sets of samples were immersed for 15 minutes in tap water at 55° F. and then air dried at (a) a temperature of 70° F. with the humidity at 25%; (b) 70° F., humidity 30%; (c) 70° F. and 70%; (d) 75° F., and 95%. The samples were scored when dry. (D) Three sets of samples were immersed in tap water at temperatures of 55° F. and 180° F. for 10 minutes and 212° F. for 3 minutes then dried at 200° F. and scored. (E) One set of samples was immersed in tap water at 55° F. for 10 minutes and dried at 200° F. in the forage drier. This procedure was carried out 4 times on the same samples. Color scores were taken after each treatment. Duplicate samples were used in all tests.

All Lot II C samples of both 1944 and 1945 were tested for retention of seed color by immersing them in tap water at 55° F. for 10 minutes and drying them in the forage dryer at 200° F.

TABLE 1.—SUMMARIZED 1945 RESULTS ON THE RETENTION OF SEED COLOR OF THE VARIETIES OF TEST V WHEN EXPOSED TO THE WEATHER, STANDING UNTHRESHED SUBSEQUENT TO THEIR MATURITY, FOR 4 DIFFERENT PERIODS OF TIME. (LOT I)

Variety	0 Days	3 Days score*	10 Days score	17 Days score	24 Days score	Average omitting 0 days
XM-4	94	91	82	71	67	77.8
Huron	92	92	80	71	67	77.5
XM-76	93	89	78	68	66	75.2
CA-11	89	88	74	66	61	72.3
MA-261	94	86	77	65	61	72.2
TA418-1	93	86	76	64	61	71.8
MA131-1	92	88	76	64	58	71.5
TA399-1	93	85	76	63	59	70.8
TA185-6	91	84	74	62	60	70.0
Henry	89	86	71	63	60	70.0
MA-163	94	85	74	63	56	69.5
TA526-2 × Ap	92	83	73	62	56	68.5
Apex	92	84	74	59	53	67.5
TA357	93	81	73	59	56	67.2
TA622-3	88	82	73	59	55	67.2
CA-6	92	86	74	57	54	67.8
TA998-4	88	81	71	59	56	66.8
XM76-1 × Th	91	75	72	61	59	66.8
TA700-1 × Ap	89	80	70	59	56	66.2
TA1001-2	86	78	69	57	53	64.2
TA622-2 × Ap	89	74	70	59	54	64.2
TA296-3	91	80	67	55	52	63.5
Regent	82	71	63	57	52	60.8
Thatcher	83	76	65	52	46	59.8
Sig. diff. at 5% level		6.4	5.8	5.2	6.1	

* Each score is the mean of six replicates.
Abbreviations: XM—(sib Apex-41 × sib Apex-660) × Marquis; CA—Comet × Apex; MA—Marquis × Apex; TA—Thatcher × Apex; Th—Thatcher; Ap—Apex.

VARIANCE ANALYSIS (after 24 days of exposure)

Source of error	Sum of squares	Degrees of freedom	Mean square	F value	5% point	1% point
Total	7578	143				
Varieties	3331	23	144.8	4.09	1.60	1.94
Error	4247	120	35.4			

Mean = 57.4 SE_v = 2.43 Necessary difference = 6.07 SE_v% = 4.23

RESULTS

In the 2 years 1944 and 1945, a total of 152 varieties and hybrid lines of wheat were tested for their retention of seed color. Owing to the large amount of data only the results of Test V in 1945 will be given in detail. There results are shown in Tables 1 to 5, inclusive.

The results on Lot I of Test V are given in Table 1 the varieties being arranged in descending order of their average scores. Statistical analysis was applied to the results from each date on which color scores were taken. Significant differences were found to exist between the varieties and lines tested. The significant difference calculated for the results of each date divided the varieties into 3 levels of resistance. Huron, XM-4, XM-76 and MA-261 showed high resistance, while Thatcher, Regent and TA1001-2 showed low resistance to seed bleaching. The remaining varieties were more or less intermediate in their retention of seed color. Although the varieties lost color progressively as the time of exposure increased from 3 to 24 days, their relationships were not significantly changed. For example, XM-4 and Huron remained high while Thatcher and Regent remained low. This was further substantiated by calculating interactions using all possible combinations of results at the four scoring dates. In no case were the interactions significant at either the 5% or the 1% level as shown by the first six interactions given in Table 5.

From the close agreement between the results of each of the four scoring dates it is apparent that even the 3 and 10 day results are a reliable indication of the ability of a variety to resist seed bleaching. It is also of interest to note that after 17 days exposure the varieties tended to lose color at a much slower rate.

TABLE 2.—SUMMARIZED 1945 RESULTS ON THE RETENTION OF SEED COLOR OF THRESHED GRAIN OF THE VARIETIES OF TEST V WHEN EXPOSED TO THE WEATHER FOR 7 DIFFERENT PERIODS OF TIME SUBSEQUENT TO MATURITY. (LOT IIA)

Variety	0 Days score	1 Day score*	2 Days score	3 Days score	6 Days score	10 Days score	15 Days score	20 Days score	Average omitting 0 days
XM-4**	94	94	94	92	85	77	76	73	84.4
XM-76	93	92	92	89	84	78	76	70	83.0
Huron	92	91	90	88	85	78	77	71	82.9
MA-261	94	94	93	91	83	76	72	70	82.7
TA418-1	93	93	92	90	81	75	74	69	82.0
TA399-1	93	93	92	89	81	73	71	66	80.7
MA-163	94	93	92	89	80	72	69	66	80.1
MA131-1	92	91	90	87	80	74	71	67	80.0
TA357	93	92	91	89	81	72	69	65	79.9
TA185-6	91	91	91	88	80	72	70	66	79.7
XM76-1 × Th	91	90	90	87	79	72	69	66	79.0
Henry	89	89	88	86	81	73	70	64	78.7
CA-11	89	88	88	85	79	72	69	66	78.1
TA526-2 × Ap	92	92	91	88	79	69	66	62	78.1
TA622-2 × Ap	89	89	88	86	79	70	67	66	77.9
CA-6	92	91	90	87	77	70	64	62	77.3
Apex	92	91	90	86	76	68	65	63	77.0
TA700-1 × Ap	89	89	88	85	77	69	65	61	76.3
TA998-4	88	88	87	85	76	68	65	60	75.6
TA296-3	91	90	88	84	77	67	63	60	75.6
TA1001-2	86	86	85	82	77	69	66	63	75.4
TA622-3	88	87	87	84	76	68	63	59	74.8
Regent	82	81	81	79	76	68	65	60	72.9
Thatcher	83	82	81	80	72	62	58	55	70.0
Sig. diff. at 5% level						4.6		4.8	

* Each score is the mean of six replicates.
** See list of abbreviations given under Table I.

The results of Lot IIA and Lot IIB are presented in Tables 2 and 3, respectively. The varieties are arranged in descending order of average score. The observations from the 10 and 20 day exposures showed statistically significant differences between varieties. The significant difference calculated for each of the two dates of each test again showed XM-4, Huron, XM-76 and MA-261 to possess high resistance, while Thatcher, Regent and TA1001-2 showed low resistance to bleaching. The interactions between (a) the 10 and 20 day exposures of Lot IIA, (b) the 10 and 20 day exposures of Lot IIB, (c) the 10 day exposure of Lots IIA and IIB and (d) the 10 day exposure of Lots IIA and I all lacked significance. Thus the varieties reacted in a similar manner when exposed to the weather whether as unthreshed heads or as threshed grain.

TABLE 3.—SUMMARIZED 1945 RESULTS ON THE RETENTION OF SEED COLOR OF THRESHED SEED OF THE VARIETIES OF TEST V WHEN EXPOSED TO THE WEATHER FOR 7 DIFFERENT PERIODS OF TIME SUBSEQUENT TO MATURITY. (LOT IIB)

Variety	0 Days score	1 Day score*	2 Days score	3 Days score	6 Days score	10 Days score	15 Days score	20 Days score	Average omitting 0 days
XM-4**	94	90	73	72	71	70	66	64	72.3
Huron	92	88	71	71	69	69	64	61	70.4
XM-76	93	88	71	70	69	69	64	60	70.1
MA-261	94	89	70	70	68	67	62	60	69.4
TA399-1	93	89	69	68	66	65	59	57	67.6
TA418-1	93	87	70	69	66	64	59	56	67.3
MA-163	94	88	68	67	65	63	59	57	66.7
TA-357	93	86	69	67	65	64	59	56	66.6
CA-6	92	86	67	67	66	65	59	55	66.4
TA185-6	91	86	69	67	65	63	58	55	66.1
CA-11	89	85	68	67	65	64	58	54	65.9
MA131-1	92	86	67	67	65	63	58	55	65.9
Henry	89	85	68	67	65	63	57	55	65.7
XM76-1 × Th	91	85	67	67	65	63	57	53	65.3
TA526-2 × Ap	92	86	68	67	64	62	57	54	65.4
TA622-2 × Ap	89	86	68	67	64	63	56	54	65.4
Apex	92	87	66	66	63	60	55	52	64.1
TA998-4	88	85	67	65	63	61	55	53	64.1
TA700-1 × Ap	89	85	66	64	61	59	54	52	63.0
TA296-3	91	83	65	64	61	59	53	50	62.1
TA622-3	88	82	64	63	61	59	52	50	61.6
Regent	82	79	63	62	60	58	54	50	60.9
TA1001-2	86	81	64	62	59	59	53	48	60.9
Thatcher	83	79	60	58	56	54	49	46	57.4
Sig. diff. at 5% level						4.5		5.3	

* Each score is the mean of six replicates.
** See list of abbreviations given under Table 1.

Bleaching appeared to be caused chiefly by alternate wetting and drying. Exposure to sun, wind and possibly slight dew brought about some bleaching, as shown by Table 2, when rain did not occur until the fourth day of exposure. On the other hand, less than $\frac{1}{10}$ inch of rain on the first day of exposure caused a striking loss of color in all of the samples of Lot II B (Table 3).

Table 4 gives the results of Lot IIC and Lot III as compared with the results of Lots I, IIA and IIB after 10 days exposure. Very close agreement between the results of the 5 treatments is apparent from the data. Statistical analyses of the results on Lot IIC and Lot III, as well as the interactions calculated between Lot IIC and Lots I, IIA and IIB, respectively, and between Lot I and Lot III confirm this close agreement. The results of the above interactions are given in Table 5.

TABLE 4.—COMPARISON OF THE RESULTS FROM 5 DIFFERENT METHODS OF TESTING THE VARIETIES AND HYBRID LINES OF TEST V FOR RETENTION OF SEED COLOR

Variety	0 Date	Lot I*	Lot IIA	Lot IIB	Lab. Dryer Lot IIC	Lot III
XM-4**	94	82	77	70	73	66
Huron	92	80	78	69	71	66
XM-76	93	78	78	69	71	62
CA-11	89	74	72	64	67	60
MA-261	94	77	76	67	68	61
TA-418-1	93	76	75	64	65	59
MA-131-1	92	76	74	63	67	57
TA-399-1	93	76	73	65	67	57
TA-185-6	91	74	72	63	67	57
MA-163	94	74	72	63	66	57
Henry	89	71	73	63	67	57
TA-526-2 × Ap	92	73	69	62	63	55
TA-357	93	73	72	64	64	55
Apex	92	74	68	60	65	55
TA-998-4	88	71	68	60	63	54
XM-76-1 × Th	91	72	72	63	64	58
TA-622-3	88	73	68	59	64	53
CA-6	92	74	70	65	64	55
TA-700-1 × Ap	89	70	69	59	63	56
TA1001-2	86	69	69	59	63	53
TA-622-2 × Ap	89	68	70	63	67	56
TA-296-3	91	67	67	59	63	51
Regent	82	63	68	58	60	54
Thatcher	83	65	62	54	58	48
Sig. diff. at the 5% level		5·9	4·6	4·5	4·4	5·2

* Lot I, Lot IIA and Lot IIB—results of 10 days exposure.
** See abbreviations given under Table I.

The agreement between Lot III results and those of Lots I and II suggests a relationship between seed bleaching and earliness of maturity. Correlations on this relationship were worked out for every test in 1944 and 1945 and in all cases they were significant and positive the lowest r value being .56.

The results of 2 years of testing using 4 treatments and 16 varieties and lines are given in Table 6. The results on Lot I in 1944 are in close agreement with the 1945 results, and with the Lot IIC results for the 2 years. The Lot IIC results are very consistent, the greatest variation shown by any one variety being only 3%. The Lot IIA results are not as consistent as those for Lot I and Lot IIC. In 1944 Lot IIA encountered more wet spells than the Lot IIA material of 1945, consequently, all scores are lower except those for Apex, MA-163 and Regent. In Lot IIB the

TABLE 5.—THE SIGNIFICANCE OF 14 INTERACTIONS BETWEEN DIFFERENT LOTS AND BETWEEN VARIOUS DATES WITHIN LOTS OF TEST V IN 1945

Interaction	F value	5%	1%
1. Lot I 3 vs. 10 days	0.62	1.55	1.85
2. Lot I 3 vs. 17 days	.95	1.55	1.85
3. Lot I 3 vs. 24 days	1.07	1.55	1.85
4. Lot I 10 vs. 17 days	.44	1.55	1.85
5. Lot I 10 vs. 24 days	.56	1.55	1.85
6. Lot I 17 vs. 24 days	.27	1.55	1.85
7. Lot IIA 10 vs. 20 days	.23	1.55	1.85
8. Lot 11B 10 vs. 20 days	.22	1.55	1.85
9. Lot I (10 days) vs. Lot IIA (10 days)	1.05	1.55	1.85
10. Lot IIA (10 days) vs. Lot IIB (10 days)	.37	1.55	1.85
11. Lot I (10 days) vs. Lot IIC	.85	1.55	1.85
12. Lot IIA (10 days) vs. Lot IIC	.63	1.55	1.85
13. Lot I (10 days) vs. Lot III	.63	1.55	1.85
14. Lot IIA (20 days) vs. Lot IIB (20 days)	.58	1.55	1.85

weather conditions were reversed resulting in lower scores for all varieties in 1945 with the exception of Newthatch. While these variations are not excessively large, they do show the possibility of introducing slight errors in scoring when using the methods outlined for Lots IIA and IIB.

Tables 7 and 8 show a very close agreement between the results of laboratory trials and the field results. In all tests XM-4, Garnet, Marquis and Huron ranked high in resistance, while Thatcher, Regent and TA1001-2 ranked low in resistance to seed bleaching. It is of interest to note that all combinations of wetting and drying produced very similar results with the exception of Tests 4, 11 and 14 given in Table 7. In Test 4

TABLE 6.—COMPARISON OF RESULTS ON 16 WHEAT VARIETIES AND HYBRID LINES FROM 4 TREATMENTS OVER A 2 YEAR PERIOD†

Variety	Lot I, 10 days		Lot IIA, 10 days		Lot IIB, 10 days		Lot IIC, dryer	
	1944	1945	1944	1945	1944	1945	1944	1945
XM-4*	85	82	75	80	77	73	73	74
Marquis	83	81	77	78	77	74	74	76
Huron	83	80	74	81	72	69	73	71
Red Bobs	83	82	76	77	76	71	74	73
XM-76	84	78	73	81	75	69	70	71
MA-261	82	77	72	79	74	67	71	68
MA-131-1	81	76	73	77	75	63	70	67
Henry	80	71	72	73	73	69	72	69
Apex	77	74	71	70	70	60	68	66
MA-163	80	74	69	69	68	63	67	66
TA-622-2 × A[illegible]	76	70	70	73	69	63	66	67
Regent	75	68	65	65	65	59	65	64
Cadet	76	71	68	69	66	61	65	66
TA-1001-2	74	69	67	69	65	58	64	63
Newthatch	72	66	62	65	58	58	58	59
Thatcher	74	67	62	63	61	54	60	58

† The figures in this table were obtained from three 1944 tests and two 1945 tests and for each year were brought to a comparable basis.
* See abbreviations given under Table I.

the high temperature of 270° F. blistered the samples thus tending to distort their appearance and score. Boiling water, used in Test 14 caused swelling and later shrivelling and cracking of the bran to such an extent that scores could not be taken. In Test 11 the 95% humidity was too high to permit drying before sprouting occurred, therefore, scores could not be taken.

TABLE 7.—THE SUMMARIZED* RESULTS OF 23 DIFFERENT LABORATORY TESTS ON 10 VARIETIES AND HYBRID LINES OF WHEAT FOR THE RETENTION OF SEED COLOR

	Treatment		Variety or line**										
Group symbol	Detailed procedure		Test No.	XM-4	Garnet	Marquis†	Huron	TA-622-2×Ap	TA-418-1	TA-357	TA-1001-2	Regent	Thatcher
A	Wet for 10 minutes	84° F.	1	79	79	78	68	65	67	60	59	64	59
	and dried for 30	175° F.	2	82	81	79	71	69	70	65	66	61	52
	minutes at	200° F.	3	83	79	82	76	71	74	68	67	59	58
		270° F.	4	78	69	76	73	69	69	57	77	69	56
B	Dried at 200° F.	10 min.	5	83	79	80	76	75	74	68	67	59	58
	after wetting for	30 min.	6	81	74	78	74	69	71	67	66	62	60
		75 min.	7	85	79	81	70	64	68	68	67	64	52
C	Wet for 15 minutes	25%	8	88	85	82	79	77	77	74	76	73	67
	then air-dried at	30%	9	88	85	88	81	77	78	74	73	73	65
	the humidity of	70%	10	89	88	89	80	75	73	74	72	74	71
		95%	11	—	—	—	—	—	—	—	—	—	—
D	Dried at 200° F.	55° F.	12	86	84	87	84	76	77	73	70	69	67
	after wetting for	180° F.	13	81	82	80	80	74	76	71	63	64	58
	10 minutes with	212° F.	14	—	—	—	—	—	—	—	—	—	—
	water temperatures												
	of												
E	Wet for 10 minutes	1	15	82	85	78	75	72	74	72	70	68	55
	and dried at 200° F.	2	16	68	70	71	68	66	64	58	58	60	52
	Repeated four times.	3	17	66	64	63	64	60	58	55	55	55	50
		4	18	58	56	59	55	51	55	52	51	50	47
	Field results (10	Lot I	19	82	—	81	80	72	75	73	68	63	64
	days exposure),	Lot IIA	20	77	—	77	78	70	75	72	69	68	61
	also Lot III and	Lot IIB	21	70	—	74	68	63	64	64	58	58	54
	IIC results.‡	Lot III	22	66	—	71	65	57	59	55	53	54	48
		Lot IIC	23	73	—	72	71	67	65	64	63	60	58

* Each result is the average of duplicate samples.
** See list of abbreviations given under Table I.
† The field results for Marquis were obtained by interpolation from the 1945 results of the Coop. Test of New Wheats.
‡ The variety Garnet was not included in the field tests.

The close agreement between the results of the different tests makes the selection of a desirable laboratory technique mostly a matter of convenience. Where a dryer, which can be operated at controlled temperatures, is available, Test 3 is most suitable, since a large number of samples can be tested in a very short time. If a dryer is not available Tests 7, 8 and 9 are quite suitable, although the drying time of the samples will range from 12 to 20 hours respectively, for each test.

TABLE 8.—THE RANKING OF 10 WHEAT VARIETIES AND LINES ACCORDING TO THEIR RESISTANCE TO SEED BLEACHING AFTER BEING SUBJECTED TO 23 DIFFERENT TESTS.

	Treatment		Variety or lines*										
Group symbol	Detailed procedure		Test No.	XM-4	Garnet	Marquis	Huron	TA-622-2 ×Ap	TA-418-1	TA-357	TA-1001-2	Regent	Thatcher
A	Wet for 10 minutes	84° F.	1	1	1	3	4	6	5	8	9	7	10
	and dried for 30	175° F.	2	1	2	3	4	6	5	8	7	9	10
	minutes at	200° F.	3	1	3	2	4	6	5	7	8	9	10
		270° F.	4	1	6	3	4	6	6	9	2	6	10
B	Dried at 200° F.	10 min.	5	1	3	2	4	5	6	7	8	9	10
	after wetting for	30 min.	6	1	3	2	3	6	5	7	8	9	10
		75 min.	7	1	3	2	4	8	5	5	6	8	10
C	Wet for 15 minutes	25%	8	1	2	3	4	5	5	8	7	9	10
	then air dried at	30%	9	1	3	1	4	6	5	7	9	9	10
	the humidity of	70%	10	1	3	1	4	5	7	6	9	8	10
		95%	11	—	—	—	—	—	—	—	—	—	—
D	Dried at 200° F.	55° F.	12	2	3	1	3	6	5	7	8	9	10
	after wetting for	180° F.	13	2	1	3	3	6	5	7	9	8	10
	10 minutes with	212° F.	14	—	—	—	—	—	—	—	—	—	—
	water at temperatures of												
E	Wet for 10 minutes	1	15	2	1	3	4	6	5	6	8	9	10
	and dried at	2	16	3	2	1	3	5	6	7	7	9	10
	200° F. Repeated	3	17	1	2	4	2	5	6	8	8	8	10
	four times	4	18	2	3	1	4	7	4	6	7	9	10
	Field results (10	Lot I	19	1	—	2	3	6	4	5	7	8	9
	days exposure),	Lot IIA	20	1	—	2	3	6	4	5	7	8	9
	also Lot IIC and	Lot IIB	21	2	—	1	3	6	4	4	8	8	9
	Lot III results	Lot III	22	2	—	1	3	5	4	6	8	7	9
		Lot IIC	23	1	—	2	3	4	5	6	7	8	9

* See list of abbreviations given under Table 1.
** The variety Garnet was not included in the field tests.

DISCUSSION

This study has shown that resistance to seed bleaching is a definite varietal characteristic with wide and stable differences between varieties. The hybrid lines of Marquis crossed with Apex or Apex sibs reacted within the parental range but several of the lines from the cross Thatcher × Apex excelled Apex, the more resistant parent. The results indicate that the expectation for seed bleaching resistance is about the same as for most quantitative characteristic, viz., within the parental range with possibilities of transgressive segregation.

In the four tests conducted in 1944 and the two tests conducted in 1945, resistance to seed bleaching was found to be correlated with lateness of maturity. This largely accounts for the close agreement between the Lot I and Lot III results given in Table 4, since the resistant late varieties benefited from fewer days of exposure while the early varieties, although lower in resistance, were exposed to the weather for a longer time.

Since there is close agreement between the results of the bleaching tests carried on in the field under natural weather conditions and those carried on in the laboratory, either type of test may be used as a practical method of determining varietal resistance to seed bleaching. Owing to the labour and expense involved in field tests the laboratory tests for bleaching resistance would seem to be preferable.

SUMMARY

A total of 152 varieties and purified hybrid lines were tested for their resistance to seed bleaching under both natural and laboratory conditions at Saskatoon in 1944 and 1945. Under natural weather conditions the varieties were tested both as unthreshed heads and as threshed seeds.

Significant differences in resistance to seed bleaching were found between the varieties tested.

Close agreement was found between the results produced by natural weathering on unthreshed and threshed samples and those results obtained by the use of a laboratory technique.

Wetting and drying was the principle involved in the laboratory tests. Wetting the samples for ten minutes and then drying them either in a dryer at 200° F. or in the open air at room temperature seemed to be the most satisfactory.

Resistance to seed bleaching was found to be related to lateness of maturity.

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SCLEROTINIA SATIVA, AND RELATED SPECIES, AS ROOT PARASITES OF ALFALFA AND SWEET CLOVER IN ALBERTA[1]

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Several fungi have been found associated with root rot of alfalfa and sweet clover in Alberta. A detailed study was previously made of *Plenodomus Meliloti*, by Sanford (13), and of the related groups *Cylindrocarpon* spp. (5), and *Fusarium* spp. (6). Attention was also paid to *Sclerotinia sativa* Drayton and Groves (9) in studies on root invasion (4), and varietal resistance (7). The present paper deals mainly with continued studies on the latter species, especially with regard to prevalence, pathogenicity, host range, persistence, and cultural characteristics. Related species included for purposes of comparison are, *S. sclerotiorum* (Lib.) De Bary, a *Botrytis* of the *cinerea* type (recently renamed as *Botryotinia Fuckeliana* by Whetzel (14)), *S. Trifoliorum* Erikss., and *S. minor* Jagger. The two latter fungi, although not yet found here, cause damage to legume forage crops in other regions.

OCCURRENCE IN ALBERTA

The results of survey and isolation studies made in Alberta during the past 15 years indicate that *Sclerotinia* root rot of sweet clover and other legume forage crops is most frequently caused by the species now known as *S. sativa*. The damage was usually ascribed to *S. Trifoliorum* (12) until 1934, when the late Dr. H. H. Whetzel kindly examined several isolates from Alberta and expressed the opinion that they were distinct from previously described species. At that time the fungus was referred to as *Sclerotinia* sp. (4). However, Drayton and Groves (9), who succeeded in obtaining mature apothecia from cultures isolated from legumes and tulips, described it as a new species, *S. sativa*, in 1943 (9).

Although sometimes very destructive to sweet clover in Alberta, *S. sativa* does not occur very commonly and is probably not as important as *Cylindrocarpon Ehrenbergi* and other root-rotting pathogens previously studied (7). It is found in sweet clover fields in various sections of the province nearly every year, causing damage which varies from a trace to 50% of the plants. It has also been isolated from diseased sweet clover specimens sent from Saskatchewan. There is no indication that the disease is spreading or increasing in importance in any of the localities in which it has been found. The damage is usually confined to individual fields and does not increase unless sweet clover is re-planted or allowed to volunteer in infested fields. Occasionally the pathogen has been isolated from slightly damaged roots of alfalfa in Alberta. In other regions it has been reported as the cause of a destructive bulb rot of tulip and narcissus (9).

Under natural conditions the root rot caused by *S. sativa* has been found only in the early spring. Affected sweet clover plants usually fail to grow, or they produce very weak shoots. The roots may be rotted to varying degrees and are often completely decayed (Plate 1, A, B, and C).

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The tissues of severely rotted roots are at first soft and watery and usually covered with the cottony white mycelium of the fungus. As the soil warms up this mycelium is replaced by black sclerotial bodies of varying size, and the decayed tissues become dry and shredded, and soon disintegrate (Plate 1, D). In alfalfa stands root-rot damage caused by *S. sativa* is seldom severe enough to affect the growth of the plants. The light brown, superficial lesions produced on the upper part of the root seldom contain sclerotia (Plate 1, E), and can be diagnosed only by means of isolation.

S. sclerotiorum also causes a root rot of alfalfa and sweet clover in Alberta, but, unlike *S. sativa*, it is a warm weather parasite causing damage only during the growing season. Sweet clover is more commonly affected than alfalfa, but there is seldom serious damage to either crop. The plants are killed singly or in small patches, and the symptoms on the roots are very similar to those produced by *S. sativa*, except that the sclerotia on them are generally larger and develop more rapidly. Sclerotia of *S. sclerotiorum* have been found in several samples of alfalfa seed grown in Alberta and Saskatchewan, but they were not observed in the stems of the diseased plants. Bisby (1), however, reported finding occasional sclerotia of this species in the stems of legumes in Manitoba. Another possible source of the sclerotia in these seed samples is from the stems of Canada Thistle or other susceptible weeds growing in the alfalfa and threshed with it. During the present study *S. sclerotiorum* was isolated from diseased sunflowers, beans, carrots, parsnips, lettuce, and tomatoes. On these hosts it caused more damage than on alfalfa or sweet clover.

Neither *S. Trifoliorum* nor *S. minor* have been found on legume forage crops or other hosts in Alberta. Moreover, stem rot commonly produced on legumes in other regions (10) has never been observed here.

Botrytis sp. (*cinera* type) is frequently isolated from diseased roots of alfalfa and sweet clover in Alberta, where it usually occurs in lesions with *Cylindrocarpon Ehrenbergi* (5) or other root-rotting pathogens. Since preliminary tests indicated that this *Botrytis* could parasitize the roots of alfalfa and sweet clover under certain conditions, several isolates from different sources were included in the present investigation.

INFECTION STUDIES

Pathogenicity Tests on Alfalfa and Sweet Clover

Isolates of *Sclerotinia sativa*, *S. sclerotiorum*, *S. minor*, *S. Trifoliorum*, and *Botrytis* sp. from various hosts and sources were tested for pathogenicity on the roots of Grimm alfalfa and Arctic sweet clover. All tests were made in the field on growing plants during the summer, as well as on dormant plants in the winter. Certain isolates of each species, indicated in Table 1, were included in 5 winter tests. Plants about 1 year old were inoculated by placing oat-hull inoculum in contact with the roots in a shallow trench dug along the side of the row. For the winter tests, the plants were inoculated in the late fall and dug about the time that growth started the following spring. Notes on the summer tests were taken about 4 weeks after the plants were inoculated. The infection rating given each plant was expressed in percentage (5).

As indicated by the results of the winter tests summarized in Table 1, *S. sativa* severely attacked the roots of the dormant plants. All isolates tested were equally destructive to sweet clover, and those from tulip bulbs produced severe rotting of alfalfa. However, during summer there was only slight infection on growing plants of sweet clover, and alfalfa usually escaped. The symptoms produced in the early spring were similar to those previously described, except that the isolates from tulip bulbs caused extensive lesioning of alfalfa roots, as compared to the slight damage caused by the isolates from legumes (Plate 1, E).

TABLE 1.—RELATIVE VIRULENCE OF ISOLATES OF DIFFERENT SPECIES OF *Sclerotinia* AND *Botrytis* ON ROOTS OF ALFALFA AND SWEET CLOVER

Species	Isolate		Infection Rating[1] %					
	No	Source	Alfalfa			Sweet clover		
			Summer	Winter	Winter[2]	Summer	Winter	Winter[2]
Sclerotinia sativa	1	Alfalfa	6	33		26	100	
	2	White sweet clover	7	25	23	22	100	96
	3	White sweet clover	6	66		23	100	
	4	White sweet clover	7	39		34	100	
	5	Yellow sweet clover	7	36		31	100	
	6	Tulip bulbs (New York)	6	92	95	21	100	100
	7	Tulip bulbs (Quebec)	5	89		17	100	
	8	Tulip bulbs (Quebec)	7	58		33	98	
S. sclerotiorum	1	Alfalfa	11	11		86	35	
	2	Yellow sweet clover	20	12	26	100	53	56
	3	Carrot	30	24		84	92	
	4	Lettuce	17	22		70	40	
	5	Snap bean	9	30	34	93	64	71
	6	Tomato	7	30		96	60	
S. minor	1	Lettuce (New York)	13	25	21	91	39	36
	2	Chicory (Belgium)	70	30	39	100	87	93
	3	Potato (Quebec)	5	5		6	8	
	4	Sunflower (Quebec)	6	5		6	5	
S. Trifoliorum	1	Red Clover (Kentucky)	41	100	92	95	100	100
	2	Clover (England)	70	39		92	100	
	3	Broad bean (England)	54	61		96	60	
	4	Crimson clover (Germany)	100	96		100	100	
	5	Sweet clover (British Columbia)	94	82		100	100	
Botrytis sp (*cinerea* type)	1	Alfalfa	20	4		25	20	
	2	Sweet clover	6	7	10	15	25	29
	3	Sweet pea	28	9		15	15	
	4	Broad bean	4	24		5	32	
	5	Potato	8	10		12	10	
	6	Wheat seed	9	13		8	32	
Control			6	5	3	9	6	4

[1] Average rating of 20 plants.
[2] Five-year average.

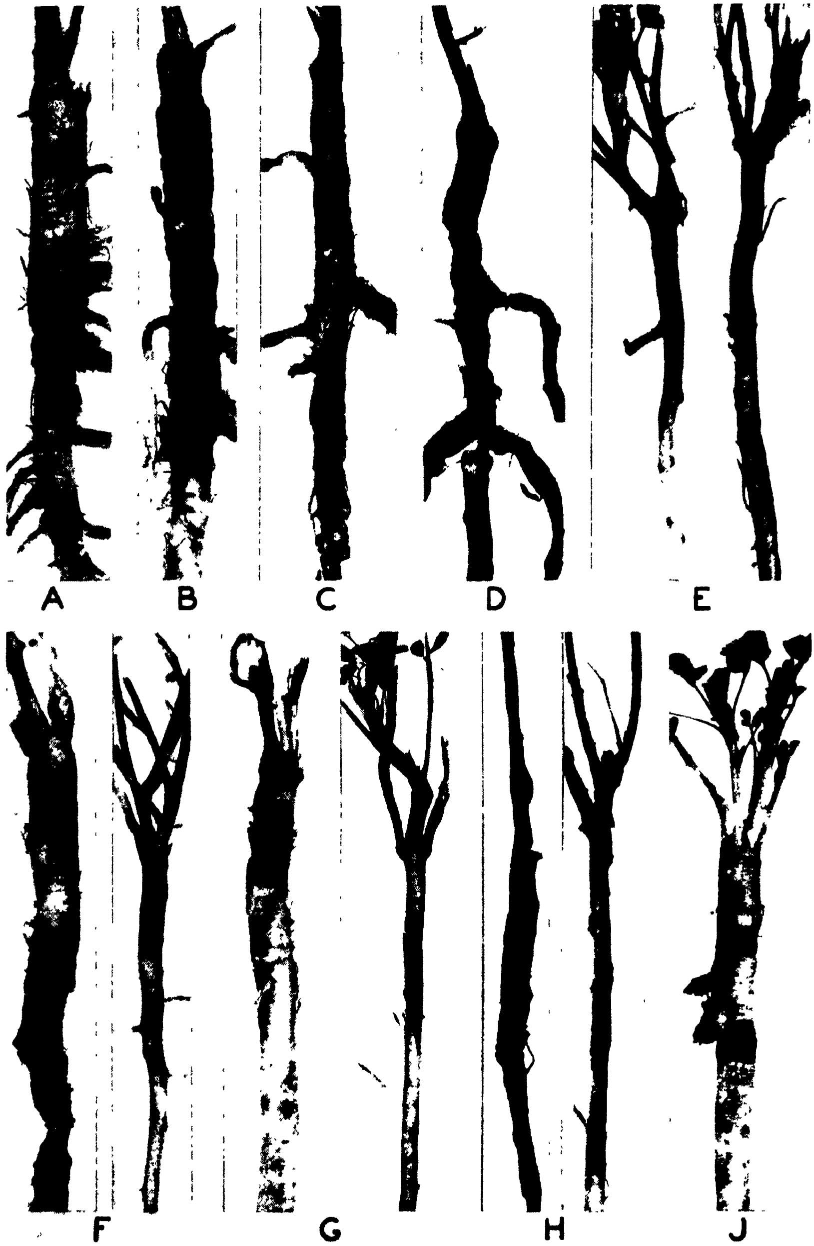

PLATE 1, A to D. Progressive symptoms produced by *Sclerotinia sativa* on roots of sweet clover in the early spring. E. Alfalfa roots attacked by *S. sativa* (left) from sweet clover, and (right) from tulips. F, G and H. Sweet clover (left), and alfalfa (right) attacked by; (F) *S. sclerotiorum;* (G) *S. minor;* and (H) *S. Trifoliorum.* J. Sweet clover attacked by *Botrytis* sp. (*cinerea* type).

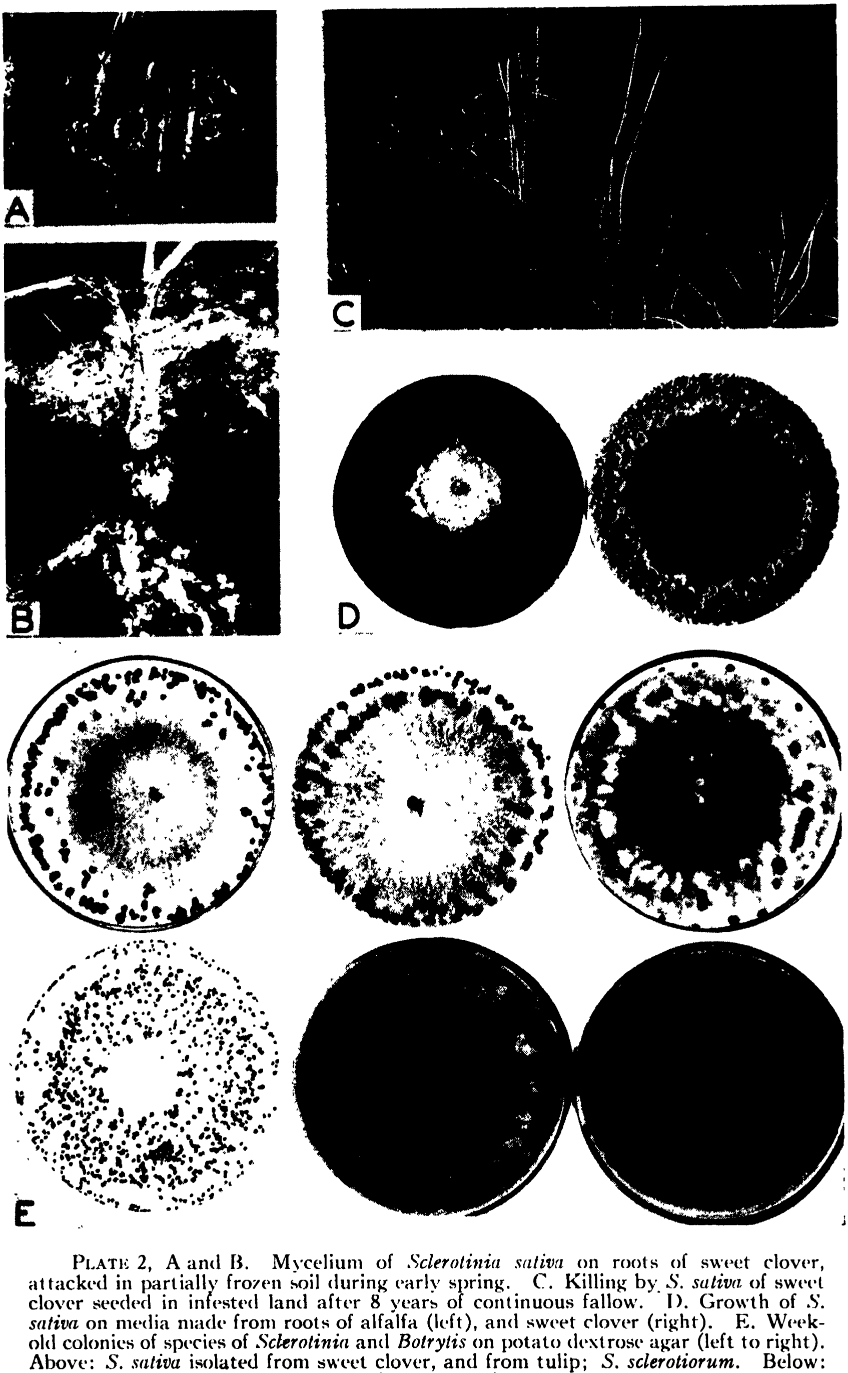

PLATE 2, A and B. Mycelium of *Sclerotinia sativa* on roots of sweet clover, attacked in partially frozen soil during early spring. C. Killing by *S. sativa* of sweet clover seeded in infested land after 8 years of continuous fallow. D. Growth of *S. sativa* on media made from roots of alfalfa (left), and sweet clover (right). E. Week-old colonies of species of *Sclerotinia* and *Botrytis* on potato dextrose agar (left to right). Above: *S. sativa* isolated from sweet clover, and from tulip; *S. sclerotiorum*. Below: *S. minor*, *S. Trifoliorum*, *Botrytis* sp. (*cinerea* type).

S. sclerotiorum was generally more virulent during the summer than in the winter tests (Table 1). In fact, periodic examinations indicated that most of the damage caused by this species in the winter tests actually occurred after the soil started to warm up prior to the time of note-taking in early May, rather than at the time of the first spring thaw, as in the case of *S. sativa*. Isolates of *S. sclerotiorum* from alfalfa, sweet clover, carrot, lettuce, snap bean, and tomato proved pathogenic in varying degrees, but all caused much more damage to sweet clover than to alfalfa (Plate 1, F).

The cultures of *S. minor* from lettuce and chicory proved highly virulent to sweet clover, especially in the summer tests, and caused slight to moderate damage to alfalfa (Table 1). The other two cultures tested were non-pathogenic on both hosts.

All cultures of *S. Trifoliorum* tested were extremely virulent and usually caused complete rotting of sweet clover roots and moderate to severe damage to those of alfalfa in both summer and winter tests (Table 1). Stem rot symptoms were not produced by this species or by any of the others studied.

The symptoms of root attack by *S. sclerotiorum*, *S. minor*, and *S. Trifoliorum* (Plate 1, F, G, and H) were similar to those described for *S. sativa*, except for the variations in severity indicated. The sclerotia produced by all 4 species on decayed roots of sweet clover varied greatly in number and size and were seldom of diagnostic value. Severe rotting of alfalfa roots, accompanied by sclerotial production, was caused only by *S. Trifoliorum* and the tulip isolate of *S. sativa*.

Cultivated Hosts

The host range of selected isolates of *Sclerotinia sativa*, *S. sclerotiorum*, *S. minor*, *S. Trifoliorum*, and *Botrytis* sp. was studied by inoculating the following forage and vegetable crops and varieties: alfalfa, *Medicago sativa* L. (Grimm), and *M. falcata* L.; sweet clover, *Melilotus alba* Desr. (Arctic), and *M. officinalis* (L.) Lam. (Common Yellow); red clover, *Trifolium pratense* L. (Altaswede); alsike clover, *T. hydridum* L.; sunflower, *Helianthus annuus* L. (Mennonite); broad bean, *Vicia Faba* L. (Windsor); bush bean, *Phaseolus vulgaris* L. (Tendergreen); lettuce, *Lactuca sativa* L. (Cosberg); tomato, *Lycopersicon esculentum* Mill. (Bounty); carrot, *Daucus Carota* L. (Chantenay); parsnip, *Pastinaca sativa* L. (Hollow Crown); cabbage, *Brassica oleracea* L. var. *capitata* L.; turnip, *Brassica Rapa* L.

Field tests were made during the summer and winter as previously described. In addition, the ability of the different isolates to cause storage rot of carrot, parsnip, cabbage, and turnip was studied. Sound specimens were inoculated by placing a small portion of mycelial inoculum in a slight wound. Duplicate tests were made at 5° and 15° C. for periods of 3 weeks and 10 days, respectively. At least 10 inoculations were made with each isolate on all hosts in each test.

S. sativa consistently caused more damage in winter than during the summer (Table 2). As in previous studies (7), *Medicago falcata* was more resistant than common alfalfa (*M. sativa*), and Common Yellow sweet

TABLE 2.—RELATIVE SUSCEPTIBILITY[1] OF CERTAIN PLANTS TO ATTACK BY SPECIES OF *Sclerotinia* AND *Botrytis*

Host plant	Tested	*S. sativa*		*S. sclerotiorum*	*S. minor*	*S. Trifoliorum*	*Botrytis* sp.	Control
		Sweet clover[2]	Tulip[2] bulbs	Sweet clover[2]	Lettuce[2]	Red clover[2]	Sweet clover[2]	
Alfalfa—*M. sativa*	Summer	T	T	L-M	L	M	T	T
	Winter	L-M	M-S	L	L-M	S	L	T
Alfalfa—*M. falcata*	Summer	O	T	L	L	M	T	T
	Winter	T-L	M	L	L	S	T	T
Sweet clover—*M. alba*	Summer	L	L	S	S	S	L	T
	Winter	S	S	M	M	S	L-M	T
Sweet clover—*M. officinalis*	Summer	L	L	S	S	S	L	T
	Winter	M	M-S	M	M	S	L-M	T
Red clover	Summer	T	T	M	L-M	S	L	T
	Winter	L-M	L-M	L	L-M	S	L	T
Alsike clover	Summer	T	T	L-M	L-M	S	L	T
	Winter	L	L	L	L-M	S	L	T
Sunflower	Summer	T	L	S	S	M	T	O
Broad bean	Summer	T-L	T-L	L	L	M	L	O
Bush bean	Summer	L	L	L	L	L-M	T	T
Lettuce	Summer	L	L	S	M	L	T	O
Tomato	Summer	O	O	L	L-M	L	T	O
Carrot	Summer	T	T	M	L	T	O	O
	Storage	T-L	T-L	S	L	T	T	T
Parsnip	Summer	O	O	M	L	T	O	O
	Storage	T	T	S	L	T	T	O
Cabbage	Storage	T	T	S	T	O	O	O
Turnip	Storage	T	T	S	L	O	O	T

[1] O—none, T—trace, L—light; M—moderate; S—severe.
[2] Source of isolate.

clover (*Melilotus officinalis*) was less severely infected than Arctic (*M. alba*). The roots of red clover and alfalfa were about equally susceptible, but those of alsike clover were only slightly damaged. In summer tests *S. sativa* was weakly parasitic on sunflower, beans, and lettuce, and did not attack tomato or parsnip. Moderate rotting, however, occurred in inoculated parsnips overwintered in the field. There was only a trace to light infection on parsnips, carrots, cabbages, and turnips stored at 5° and 15° C. The isolates from sweet clover and tulip bulbs caused a similar degree of infection on all hosts except alfalfa. As reported by Drayton and Groves (9), isolates from both sources caused severe rotting of tulip bulbs in winter tests.

S. sclerotiorum proved pathogenic to varying degrees on all hosts studied (Table 2). Root infection was moderate to severe in sweet clover, and slight to moderate in alfalfa, red clover, and alsike clover. All of these crops were more severely attacked by this species during the summer

than in the winter tests. Infection was severe on sunflower and lettuce, but only light on broad bean, snap bean, and tomato. Carrot, parsnip, cabbage, and turnip, stored at 5° and 15° C. were severely rotted, but infection was only moderate on growing roots of carrot and parsnip in the field. *S. sclerotiorum* has been reported as parasitic on a wide range of host plants in the temperate regions (1, 2, and 15).

S. minor caused about the same degree of infection as *S. sativa* on the legume forage crops in the winter tests, but usually it was more virulent during the summer (Table 2). In the field tests, infection was severe on sunflower, moderate on lettuce, light to moderate on tomato, and light on broad bean, bush bean, carrot, and parsnip. Little or no damage was caused to carrot, parsnip, cabbage, and turnip stored at 5° and 15° C. *S. minor* has been previously reported on clover (3) and on various vegetables (11).

S. Trifoliorum was more virulent on legumes than any of the other species tested (Table 2). In all tests it caused severe rotting of the roots and death of sweet clover, red clover, and alsike clover. In the case of alfalfa, both *Medicago sativa* and *M. falcata* were killed in the winter tests, and moderately damaged during the summer. Infection was moderate in broad beans, and light to moderate in bush beans. The damage was moderate in sunflower but was absent or slight in the other non-leguminous plants studied in the field and in storage. *S. Trifoliorum* is best known as the cause of stem rot of clovers (10), and is seldom reported on other hosts.

Botrytis sp. caused slight damage to forage crop legumes and broad bean. On the other hosts studied there was only a trace of infection or none, as in the controls. This fungus has been previously reported on alfalfa and clovers (3), chiefly as the cause of grey mould of the shoots and blossoms. It occurs commonly as a weak parasite or saprophyte on the dead or dying parts of many other plants.

WILD HOSTS

The host range of *S. sativa* among native plants and perennial weeds was determined by placing inoculum against the roots *in situ* in the late fall. The inoculated plants and controls were dug up for examination the following spring. The relative susceptibility of the plants studied, based on the average results obtained in 2 successive winter tests with each, was as follows:—Highly susceptible; *Achillea Millefolium* L. *Artemisia gnaphalodes* Nutt., *Aster conspicuus* Lindl., *Cirsium arvense* (L.) Scop., *Cirsium undulatum* (Nutt.) Spreng., *Helianthus* sp., *Lactuca pulchella* (Pursh) D C., *Plantago major* L., *Senecio eremophilus* Richards, *Solidago Canadensis* L., *Sonchus arvensis* L., *Taraxacum officinale* Weber, and *Urtica procera* Muhl.; moderately susceptible: *Aster laevis* L., *Heracleum lanatum* Michx., and *Potentilla* sp. Slightly susceptible; *Agastache anethiodora* (Nutt.) Britt., *Argentina Anserina* (L.) Rydb., *Chamaenerion spicatum* (Lam.) S. F. Gray, and *Vicia americana* Muhl.

Owing to decay in the controls, inconclusive results were obtained with several other native plants, but all appeared to be susceptible in some degree to attack by *S. sativa*. This pathogen has not yet been isolated from naturally infected roots of any of these plants, although its potential host range is wide. All of the perennial weeds inoculated, including Canada

thistle (*Cirsium arvense*), sow thistle (*Sonchus arvensis*), and dandelion (*Taraxacum officinale*), were severely damaged, but control by this means does not seem practical. These weeds have been previously reported as hosts of *S. sclerotiorum* (15).

No infection was obtained in winter tests of *S. sativa* on winter wheat, winter rye, and several cultivated and native species of the grass genera *Agropyron*, *Bromus*, *Festuca*, *Phleum*, and *Poa*.

FIELD STUDIES ON S. SATIVA

Disease Development

The progress of infection of sweet clover roots by *S. sativa* in the early spring was studied in the field by periodic examination of plants grown in infested soil. These plants grew normally during the first season, and there was no evidence of infection until the following spring. Observations were made at the time of the first thaw by baring a few roots on one side to a depth of about 4 inches. Thereafter examinations were made daily while the disease was progressing rapidly. Another method that gave good results was to make these observations on roots of inoculated plants in boxes of soil. These were brought in and the soil thawed out slowly at a temperature near freezing in a refrigerated room.

The first signs of infection appeared on the roots in the form of small watery areas shortly after thawing started. These decayed areas developed very rapidly and often involved the entire root system within less than a week. By this time the decayed roots were usually covered with the cottony white mycelium of the fungus (Plate 2, A and B). This mycelium followed the rootlets from plant to plant and penetrated to a very limited extent into the surrounding soil. Even at this stage the soil was often still partially frozen. When it warmed up and growth started in the control plants, the mycelium was replaced by sclerotia and the decayed tissues became dry and shredded.

Spread of Pathogen in Soil

Since the early spring observations indicated that *S. sativa* spreads mainly from one plant to another by means of contiguous roots or rootlets, a field study was made to determine if the fungus could grow directly through the soil. In the late fall, inoculum was placed in trenches about 2 inches deep, at varying distances from rows of sweet clover. These trenches were dug parallel to the rows and all roots and rootlets were removed from the intervening soil. In the following spring, infection occurred on all plants having roots in actual contact with inoculum. When the inoculum was $\frac{1}{4}$ inch distant from the roots, the average infection was 42%, and when 1 inch, 5%. At greater distances no damage occurred. However, when inoculum was placed in a closely planted row or stand the pathogen spread and killed the plants to a distance of at least 6 inches. Similar results were obtained with inoculum placed on the surface of the soil, except that usually the fungus spread to a lesser extent above than below ground. Davis (8) found that *S. sclerotiorum* progressed only 5 cm. from the centre of infection on the surface of the soil and that healthy cabbage plants were infected by contact with diseased individuals.

Persistence in Soil

Field studies were made on the ability of *S. sativa* to persist in the soil in the absence of a host plant. A plot at Edmonton, in which sweet clover was severely damaged by *S. sativa* in the early spring of 1937, was subsequently fallowed, except for successive portions replanted each year to sweet clover. These plantings all grew well during the first season, but those of the first 4 years were completely killed out by *S. sativa* in the early spring of the second season. Since then a small portion of the plants, increasing from 5% in 1942 to 15% in 1945, have survived each spring. These plants were weakened, however, by partial rotting of the roots, and the fungus still caused extremely severe damage in the early spring of 1945 in the portion of the plot that had been summer-fallowed for 8 years (Plate 2, C). These results have been confirmed in other plots and fields where it has been found impossible to maintain a new stand of sweet clover following root-rot damage caused by *S. sativa*. Annual crops and grasses were unaffected, even when planted immediately in such land, and alfalfa was seldom seriously damaged.

CULTURAL STUDIES ON SCLEROTINIA SPP.

Longevity of Sclerotia

Field observations indicated that the sclerotia were probably not responsible for the long continued persistence of *S. sativa* in the soil. Sclerotia were abundant in the diseased root tissues of sweet clover following infection in the early spring, but disappeared as the tissues disintegrated. By September only a few soft fragments of sclerotia remained in the shells of the old decayed roots.

In laboratory experiments, sclerotia of *S. sativa* and *S. sclerotiorum*, in lots of 50, were made up in cheesecloth-covered packets with an equal volume of air-dried soil. These packets were stored at room temperature for 6 months in cans of soil at three moisture contents, namely, air dry, about 55%, and 70 to 80% m.h.c., respectively. Within a month the sclerotia of *S. sativa* stored in the moist and wet soils were almost completely decomposed and unidentifiable. Those stored in the dry soil remained sound for the duration of the experiment. The sclerotia of *S. sclerotiorum* were also decomposed in a month in the wet soil, but did not start to decay until after 6 months in the moist soil. In dried herbarium specimens sclerotia of both species retained their original form indefinitely. Sclerotia of *S. sativa* failed to produce mycelium after 3 years storage, while those of *S. sclerotiorum* still remained viable after 7 years. Brown and Butler (2) noted the general tendency of sclerotia of *S. sclerotiorum* to decay in moist soil, but found that they could live for 11 years under dry conditions.

Apothecia and ascospores of *Sclerotinia* spp. have not been observed under natural field conditions in Alberta, and apparently do not aid in the dispersal of these fungi as is the case in warmer, more humid regions (2, 10). Apothecia of *S. sativa* have not been reported in nature. However, they were obtained by Drayton and Groves (9) from cultures in the laboratory and greenhouse.

Influence of Media on Growth

To check on host relationships, isolates of *S. sativa, S. sclerotiorum, S. minor, and S. Trifoliorum* were cultured on media made from the extracted root juices of several varieties of alfalfa and sweet clover. These media consisted of 5% root decoction in water agar. Similar results were obtained from the root juices sterilized by steam or passed through a Berkefeld filter. The media from alfalfa roots proved to be much less favourable than those from the sweet clover both for growth and sclerotial formation, which results agree with the data obtained in the infection studies. These differences were particularly marked in the case of the legume isolates of *S. sativa* (Plate 2, D), and occurred to about the same degree when different varieties of alfalfa and sweet clover were used.

Potato-dextrose agar was the best general medium for *S. sativa* and the other species. Fair results were given by Czapek's peptone-dextrose and malt agars, but Dox's inorganic salt, Molisch's salt-peptone, bean-pod, and corn-meal agars were unsatisfactory. In confirmation of field results, little or no growth occurred in natural soil, even when it was steam sterilized. A soil medium, sterilized or non-sterilized, containing about 10% by volume of ground oat hulls or other organic matter, however, favoured rapid growth and was sometimes used for the preparation of inoculum.

A comparative study was made of the cultural characteristics of representative isolates of *Sclerotinia* spp. and *Botrytis* sp. when grown on potato-dextrose agar. As shown in Plate 2, E, the isolates of *S. sativa* from sweet clover and tulips were similar in appearance and produced a whitish, close-growing mycelium and fairly numerous mid-sized sclerotia. In test-tube culture these isolates sometimes developed a fluffy, greyish, aerial mycelium resembling that of *Botrytis* sp. *S. sclerotiorum* and *S. Trifoliorum* produced more aerial mycelium and larger sclerotia than *S. sativa* (Plate 2, E). In *S. Trifoliorum* the sclerotia developed more slowly than in *S. sclerotiorum*, and were often partially covered by the mycelium. Most isolates of *S. minor* produced a scant mycelium and extremely numerous, small sclerotia. All isolates of *Botrytis* sp. developed an abundant, greyish aerial mycelium and no sclerotia, except occasionally when freshly isolated. After being cultured for a long period some isolates, particularly of *S. sativa*, tended to run-out and ceased to produce typical mycelium and sclerotia.

Influence of Temperature on Growth

Representative isolates of *S. sativa, S. sclerotiorum, S. minor, S. Trifoliorum*, and *Botrytis* sp. were grown in quadruplicate plates of potato-dextrose agar at temperatures ranging from − 4° to 34° C. The average results obtained are summarized in Table 3.

In the low-temperature series all species grew slowly at 1° C., but only *S. sativa* grew at temperatures below freezing. This species grew slowly even at − 4° C. on frozen agar, producing a compact colony about 20 mm. in diameter in one month. At temperatures from 5° to 10° C. sclerotia were produced slowly and sparingly by all species.

S. sativa and *S. Trifoliorum* produced most growth at 17° C., and apparently both have an optimum below 20° C. Best growth of *S. minor* and *Botrytis* sp. occurred at 20° C., and of *S. sclerotiorum* at about 25° C.

TABLE 3.—INFLUENCE OF TEMPERATURE ON GROWTH OF *Sclerotinia* SPP. AND *Botrytis* ON POTATO-DEXTROSE AGAR

Species	Average diameter of colony in millimetres									
	10 days					3 days				
	1° C.	5° C.	10° C.	14° C.	17° C.	20°C.	25°C.	28°C.	31°C.	34°C.
S. sativa	7	28	90	25	32	30	25	6	0	0
S. sclerotiorum	5	20	85	59	83	86	90	48	6	0
S. minor	6	18	77	21	25	34	27	7	0	0
S. Trifoliorum	15	19	50	27	29	26	15	0	0	0
Botrytis sp. (*cinerea* type)	11	33	77	42	49	53	45	8	0	0

Growth of all the species dropped off rapidly at the higher temperatures, and none of them grew at 34° C. The colonies of *S. Trifoliorum* ceased to develop at 28° C., those of *S. sativa*, *S. minor*, and *Botrytis* sp. at 29° to 31° C., and *S. sclerotiorum* at about 32° C. Growth of *S. sativa*, *S. minor*, and *S. Trifoliorum* was relatively slow at temperatures above 10° C., as compared to that of *S. sclerotiorum*.

DISCUSSION

Although the species of *Sclerotinia* studied herein are potentially capable of causing severe root-rot damage in sweet clover, they are not yet very destructive in Alberta. In fact *S. sativa* and *S. sclerotiorum*, the only species found in this region, occur less frequently and cause less general damage than most of the other root- and crown-rotting pathogens previously studied (7). Apparently our climatic conditions do not favour the development and spread of these fungi, perhaps being too cool and dry for the development of the stem-rot symptoms and apothecia commonly produced by *Sclerotinia* spp. in warmer, more humid regions (2, 10). When the above-ground parts of the plants are not infected there is less opportunity for the spread of the mycelium and sclerotia. Extensive distribution of these pathogens is even more effectively prevented when there are no ascospores to be widely disseminated by the wind. Thus, under Alberta conditions, it appears that *Sclerotinia* spp., once established in a given soil, are mainly limited to local spread through contact between the roots of diseased and healthy plants, or by the transfer of infective material during cultural operations. Bisby (1) concluded that climatic conditions in Manitoba did not favour maximum development of the disease caused by *S. sclerotiorum*.

The recently described species *S. sativa* was of particular interest in this investigation. To date it has been found only on roots of alfalfa and sweet clover in Western Canada and on bulbs of tulip and narcissus in Eastern Canada and the United States (9). This limited natural host range will probably be extended in the future, since the present study has shown that a number of other species are susceptible to attack by *S. sativa* during early spring. As a parasite of the dormant plants, it causes damage that may be overlooked or confused with true winter-killing. It would be interesting to know if *S. sativa* is native or introduced. Although it has

not yet been isolated from naturally infected native hosts, apparently it is harboured by a wide range of susceptible plants in nature. When established in a sweet clover field, this species is not active during the growing season, but attacks the dormant plants of sweet clover or other highly susceptible hosts only during the early spring. It also possesses an unusual ability to remain viable in the soil for years, even in the absence of a host. Since its sclerotia are short-lived in moist soil, the fungus apparently persists mainly as a semi-saprophytic mycelium that can live more or less indefinitely on decaying organic matter. Fortunately, many other crops can be safely grown in old sweet clover fields infested with *S. sativa.*

SUMMARY

Sclerotinia sativa is sometimes very destructive to sweet clover in Alberta during the early spring, but it seldom attacks alfalfa and is not as yet very commonly distributed. *S. sclerotiorum* occasionally causes damage to alfalfa and sweet clover during the summer, but it occurs more commonly on sunflowers and vegetable hosts. *S. minor* and *S. Trifoliorum* have not yet been found on any host in Alberta.

S. sativa is distinctly a low-temperature parasite of dormant plants. It rapidly invades the roots of its hosts even as the frozen soil thaws during early spring, but its progress is arrested when plant growth begins. In winter inoculation tests in the field it severely attacked sweet clover, but caused slight to moderate damage to alfalfa and red clover, and only slight injury to alsike clover. Parsnip and twenty perennial wild plants were also susceptible. *S. sclerotiorum* was more virulent during summer than early spring and injured sweet clover more than alfalfa, red clover, or alsike clover. *S. minor* attacked the legume forage crops to about the same degree as did *S. sativa*, but it caused most damage during the summer. *S. Trifoliorum* was more virulent on the legume forage crops and beans than any of the other species tested, but did not cause serious damage to any non-leguminous host except sunflower. *Botrytis* sp. (*cinerea* type), frequently associated with root rot of alfalfa and sweet clover in Alberta, was seldom more than weakly virulent on any of the hosts studied.

Excepting *S. sativa*, where the isolates from tulip bulbs were much more virulent to alfalfa than those obtained from legumes, and certain non-pathogenic cultures of *S. minor*, there was little evidence of variation in virulence among the isolates of a given species.

S. sativa persisted in fallowed soil and severely damaged sweet clover even after a period of 8 years. However, its sclerotia decayed rapidly in moist soil. No apothecia of this or the other species studied have been found under natural conditions in Alberta.

In pure culture, *S. sativa* produced sclerotia intermediate in size between those of *S. minor* and *S. sclerotiorum.* Alfalfa root media were much less favourable than sweet clover root media, both for growth and sclerotial formation. *S. sativa* and *S. Trifoliorum* grew best at 17° to 19° C., *S. minor* and *Botrytis* sp. at 20° C., and *S. sclerotiorum* at about 25° C. Sclerotial formation was inhibited or retarded in all species at temperatures below 10° C. Growth ceased at about 30° C. in all species.

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SOME FACTORS AFFECTING APPLE YIELDS IN THE OKANAGAN VALLEY

IV. ORGANIC MATTER CONTENT OF SOIL[1]

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Both research and practical experience have indicated that organic matter in the soil is essential to successful agriculture. This finding has been applied not only to general crop production, but to tree fruits as well. Investigators in Pennsylvania (1, 5, 9) have found a close relationship between the growth of cover crops and the subsequent performance of fruit trees. This relationship has been attributed primarily to the effects of cover crops in increasing the humus content of the soil. Similar conclusions have been reached by other investigators (4, 6, 10, 11).

The literature on the relationship of humus in the soil to plant and tree performance has been effectively covered by a number of authors (1, 3, 12), and there is no need to cover it again in this paper. Special mention, however, should be made of a report by Cummings (3) in 1937. The organic matter contents of soil samples from 93 Baldwin orchards in New York State were determined by analysing for the total organic carbon and multiplying the results by 1.724. No consistent relationship was found between the organic matter content of the soil and tree yield, or between organic matter and tree size. It was concluded that the organic matter content at any one time is not as important as are other factors associated with the organic matter. Chief among these is considered to be the rate of "turnover" of organic materials. A high rate of turnover is accomplished when organic materials are added to the soil in large quantity and then decompose quickly. In spite of the lack of correlation between organic matter content and yield, humus is still considered by the author (3) to be necessary for orchard soils.

PROCEDURE

A total of 74 plots of mature McIntosh trees was selected in grower-owned orchards in the Okanagan Valley in British Columbia, in 1937. In each plot, soil samples were obtained during the months of April and May, 1940. The procedure used was to select a representative tree in each plot, and to make 10 borings with a soil auger around the tree, at distances of 4 to 10 feet from the trunk. The soil was composited at successive depths of 0 to 8 inches, 8 to 24 inches, and 24 to 60 inches. It was then screened through a 3 mm. sieve and allowed to air dry. The procedures used in laying out the plots, taking the tree records over a 6-year period, and obtaining the soil samples, have been outlined in greater detail in previous papers of this series (13, 14).

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The McIntosh plots were selected in 1937 primarily on the basis of tree type, soil texture and soil depth, and little attention was paid to type of cover crop. In addition, no attempt was made to influence the growers in their choice of cover crops or in their methods of handling them.

The only records obtained on the cover crops grown were observational notes, made during the 6 years (1937 to 42) of tree recording. All of the plots were under irrigation, and cover-cropped, and a few were in permanent alfalfa sod, and some in permanent grass sod. These were usually cultivated once a year, in the late fall or early spring. A few plots were in sweet clover, hairy vetch, fall rye, or oats. These were usually cultivated twice a year, once as above and once in midsummer or late summer. In a large proportion of the plots, leguminous cover crops had been planted by the growers, but they had reverted to general mixtures of cover crops, weeds, and grasses. In only two cases was organic matter known to have been applied in other form than as green manure. In both of these cases, some poultry manure had been applied.

Mechanical analyses of the soil samples were made by the hydrometer method of Bouyoucos (2).

The procedure used for determining the organic matter content of the soil was a modification of the hydrogen peroxide method of Robinson (8): weigh a 125 ml. Erlenmeyer flask; add approximately 2 gm. of soil, and weigh again. Add 20 ml. of 3% hydrogen peroxide, and set on steam bath for 30 to 45 minutes. Add another 10 ml. of 3% hydrogen peroxide, washing down the inside of the flask with it. Replace on steam bath for 30 to 45 minutes. Add a further 10 ml. of hydrogen peroxide, place on steam bath and allow to evaporate to dryness. Remove from steam bath, leave near balances for one hour or more to come to moisture equilibrium with the air, and weigh. The loss in weight is considered to represent the amount of organic matter lost by oxidation. The percentage of organic matter thus determined was then adjusted for the percentage of gravel discarded when the soil samples were originally taken, on the assumption that the organic matter content of the gravel was zero.

It was found that the weight of the flasks varied somewhat with the humidity of the air. In order to correct for this, approximately 2 gm. of soil were added to each of the 2 125-ml. Erlenmeyer flasks. These flasks were then weighed every time the other flasks were weighed, so that corrections could be made for variations in air humidity. The error from this source was thereby reduced to below 0.1% of organic matter. No difficulty from manganese was encountered in this investigation.

The above procedure was found to oxidize the organic matter to the point that further additions of hydrogen peroxide did not make any measurable difference in the weight of the soil. This was true with those samples containing the highest amounts of organic matter. It should be pointed out that all of the samples were comparatively low in their contents of organic matter.

As pointed out by Robinson (8), oxidation with dilute hydrogen peroxide does not remove all of the organic matter from the soil. In fact, after oxidation small particles of vegetable matter or coal-like material could, in some cases, still be seen with the naked eye. These residues were

apparently the most resistant portions of the organic matter in the soil. The question arises as to which is the more important measurement, that of *total* organic matter or that of *active* organic matter. In this investigation, it has been assumed that the active portion is the more important. It is realized that segregation of the active portion from the inactive portion is a very difficult matter, and that the procedure used may not be entirely satisfactory in this regard. It appears safe to assume, however, that the results obtained bear a closer relationship to the active organic matter content than to the total organic matter content.

RESULTS

The terminal lengths and yields of the McIntosh trees in the 74 plots have already been reported for the individual trees (13) and for the plot averages (14). The clay, colloid, and organic matter contents of the soils are summarized in Table 1. Since the records on the soil samples taken below a depth of 24 inches have not been used in the correlations reported in this paper, only the 0 to 8 and 8 to 24 inch data are presented in the table. The 0 to 24 inch percentages of organic matter (last column of Table 1) have been obtained by weighting the figures for the 0 to 8 and 8 to 24 inch samples by their respective depths. Other soils data have been presented in the second paper of this series (14).

Difficulties were encountered in attempting to determine the effects of each kind of cover crop on the organic matter content of the soil and on tree performance. This was due in part to the fact that no measurements were taken of cover crop growth. It was also due to the fact that there were so many different cover crops, and so many combinations of cover crops and fertilizers. Finally, many of the growers had changed their cover-cropping schedules prior to soil sampling. As a result, the relationships between cover crop on the one hand and soil and tree characteristics on the other hand were inconclusive, and will not be reported here.

TABLE 1.—CLAY, COLLOID, AND ORGANIC MATTER CONTENTS OF SOIL SAMPLES

Plot No.	Sand		Silt		Clay		Colloid		Organic matter		
	0 to 8	8 to 24	0 to 8	8 to 24	0 to 8	8 to 24	0 to 8	8 to 24	0 to 8	8 to 24	0 to 24
	%	%	%	%	%	%	%	%	%	%	%
P2	37 4	29.4	46.8	65.4	15.8	15.2	27.2	29.0	2.9	1.3	1.8
P3	39.0	38.2	47.8	51.4	13.2	10.4	24.6	20.6	2.7	1.0	1.6
P4	41.6	27.6	44.0	59.4	14.4	13.0	23.4	30.2	2.6	1.1	1.6
P1	21.2	19.4	62.2	62.8	16.6	17.8	32.2	30.2	1.5	0.6	0.9
P9	52.8	51.0	38.2	35.8	9.0	13.2	17.0	22.2	1.8	1.0	1.3
P10	65.2	64.8	25.0	31.0	9.8	4.2	24.4	8.2	1.2	0.7	0.9
P5	43.[illegible]	39 4	42 4	46 0	14.2	14.6	22.2	27.0	2.3	0.9	1.4
P7	55.4	54.4	34.0	31.4	10.6	14.2	19.4	19.4	2.0	0.7	1.1
P6	48.0	54.6	44.8	33.2	7.2	12.2	21.0	18.2	3.2	0.4	1.3
S12	65.2	62.2	25.6	24.4	9.2	13.4	16.0	13.6	1.8	0.2	0.7
S10	67.2	72.2	22.6	20.4	10.2	7.4	15.8	11.0	1.7	0.3	0.8
T2	53.8	41.8	29.8	38.0	16.4	20.2	28.4	35.8	2.2	0.5	1.1
T3	76.8	75.4	16.6	21.6	6.6	3.0	13.6	8.2	1.9	0.1	0.7
T6	47.4	53.4	39.8	36.0	12.8	10.6	24.2	20.6	0.8	0.6	0.7
T7	58.8	61.6	41.0	27.0	10.2	11.4	23.2	16.4	1.6	0.8	1.1

TABLE 1.—CLAY, COLLOID, AND ORGANIC MATTER CONTENTS OF SOIL SAMPLES—*Concluded*

Plot No.	Sand		Silt		Clay		Colloid		Organic matter		
	0 to 8	8 to 24	0 to 8	8 to 24	0 to 8	8 to 24	0 to 8	8 to 24	0 to 8	8 to 24	0 to 24
	%	%	%	%	%	%	%	%	%	%	%
T8	51.6	49.0	29.8	27.0	18.6	24.0	28.2	34.0	1.7	0.7	1.0
T9	73.8	76.0	22.0	19.0	4.2	5.0	11.0	11.0	1.4	0.2	0.6
K1	67.2	62.8	23.4	31.0	9.4	6.2	16.6	11.6	1.4	0.2	0.6
K2	65.4	70.0	24.4	21.8	10.2	8.2	14.6	12.8	1.8	0.6	1.0
K6	64.2	70.2	22.0	22.6	13.8	7.2	18.0	13.2	2.0	0.5	1.0
K21	64.2	70.2	25.0	20.0	10.8	9.8	17.2	15.8	1.7	0.6	1.0
K7	66.6	66.0	21.8	22.8	11.6	11.2	26.8	17.0	1.7	0.8	1.1
K9	56.8	59.6	29.2	30.0	14.0	10.4	21.8	16.4	2.1	0.9	1.3
K27	56.8	68.8	27.0	22.8	16.2	8.4	24.6	12.8	2.1	0.1	0.8
K16	53.8	51.0	33.6	26.6	12.6	22.4	41.6	34.4	2.2	1.4	1.7
K10	55.6	62.8	29.4	26.4	15.0	10.8	20.8	16.6	1.8	0.2	0.7
K39	54.4	58.0	30.8	30.6	14.8	11.4	20.6	28.2	0.8	0.3	0.5
K53	47.8	60.2	33.6	31.0	18.6	8.8	28.4	19.6	2.2	0.5	1.1
K54	54.0	66.4	32.4	23.8	13.6	9.8	20.0	14.4	2.1	0.4	1.0
K11	53.0	70.0	33.4	21.4	13.6	8.6	25.6	12.4	2.7	0.4	1.2
K12	61.2	69.2	24.6	20.2	14.2	10.6	17.6	14.6	2.3	0.2	0.9
K13	57.8	64.2	26.4	29.2	15.8	6.6	24.0	14.2	1.9	0.3	0.8
K14	58.0	67.8	28.2	24.6	13.8	7.6	19.6	12.4	1.9	0.2	0.8
K15	56.2	67.6	32.2	25.2	11.6	7.2	19.8	14.8	1.9	0.4	0.9
K46	53.2	67.2	34.8	22.2	12.0	10.6	22.4	14.8	1.4	0.1	0.5
K51	58.6	65.4	28.6	25.8	12.8	8.8	22.0	15.6	2.0	0.4	0.9
K17	52.2	45.8	24.8	18.0	23.0	36.2	30.8	44.8	3.0	2.9	2.9
K18	25.8	13.0	33.4	24.2	40.8	62.8	50.8	73.0	3.2	2.5	2.7
K22	54.2	64.6	30.8	28.2	15.0	7.2	21.0	14.0	2.1	0.1	0.8
K44	59.2	67.4	27.0	24.8	13.8	7.8	21.4	14.6	2.8	0.5	1.3
K25	19.0	16.2	67.4	21.6	13.6	62.2	50.9	72.2	3.6	3.5	3.5
K24	64.6	73.2	23.0	16.2	12.4	10.6	17.8	15.6	1.3	0.2	0.6
K49	23.8	8.2	28.6	13.4	47.6	78.4	58.4	83.8	3.6	2.5	2.8
K8	43.8	38.2	30.6	26.4	25.6	35.4	34.2	41.4	3.1	1.9	2.3
K48	32.8	13.8	22.0	38.0	45.2	48.2	57.0	63.8	3.8	2.8	3.1
B29	47.2	72.8	44.4	21.0	8.4	6.2	13.2	10.2	1.7	0.7	1.0
B30	61.0	62.6	32.0	28.8	7.0	8.6	35.0	11.2	1.4	0.7	0.9
B31	59.6	59.8	39.4	36.6	11.0	3.6	23.4	6.4	1.8	0.9	1.2
B1	71.6	59.6	18.8	27.8	9.6	12.6	13.0	18.4	2.3	1.2	1.6
B34	65.0	56.0	24.8	33.2	10.2	10.8	16.8	19.2	1.4	1.2	1.3
B33	66.4	75.0	23.6	16.8	10.0	8.2	15.8	10.0	1.1	0.7	0.8
B38	76.8	79.4	16.6	14.6	6.6	6.0	21.6	8.0	1.5	0.8	1.0
B36	68.2	75.8	21.6	19.0	10.2	5.2	15.4	9.0	1.9	0.8	1.2
B37	59.4	66.8	27.8	26.0	12.8	7.2	20.6	12.8	2.0	0.8	1.2
G42	49.0	44.0	44.6	50.0	6.4	6.0	14.0	13.6	1.7	1.3	1.4
G50	64.4	73.2	30.2	22.2	5.4	4.6	11.6	9.2	1.7	0.8	1.1
G26	62.6	56.8	32.4	36.8	5.0	6.4	11.0	11.2	1.2	0.8	0.9
G18	75.8	78.6	17.8	14.0	6.4	7.4	10.8	11.2	1.1	0.3	0.6
G17	59.2	65.8	28.4	19.0	12.4	15.2	20.6	24.2	1.2	0.6	0.8
G19	25.2	20.4	54.4	59.2	20.4	20.4	37.2	42.6	3.6	0.7	1.7
G20	17.6	17.6	42.4	31.6	39.0	50.8	51.6	65.4	3.9	2.5	3.0
W2	54.8	48.6	20.8	14.6	24.4	36.8	29.8	40.0	3.7	3.1	3.3
W7	71.8	76.4	21.8	17.2	6.4	7.4	12.4	12.8	0.6	0.3	0.4
W6	74.0	57.2	16.8	33.0	9.2	9.8	12.8	15.6	1.1	0.3	0.6
W5	73.2	75.8	18.6	16.6	8.2	7.6	14.4	9.8	1.5	0.5	0.8
W4	74.6	73.4	19.6	18.0	5.8	8.6	11.2	11.6	0.8	0.4	0.5
W9	37.4	28.4	33.2	32.6	29.4	39.6	40.4	51.0	3.8	2.6	3.0
W8	65.2	63.4	21.2	21.4	13.6	15.2	19.2	20.4	1.8	0.5	0.9
W10	66.2	71.8	20.2	17.6	13.6	10.6	19.4	14.4	2.2	1.0	1.4
O14	52.2	55.8	29.8	25.2	18.0	19.0	26.2	24.2	2.9	1.1	1.7
O17	68.4	70.0	19.6	18.4	12.0	11.6	18.6	13.8	2.5	1.2	1.7
O15	63.8	72.0	25.0	22.0	11.2	6.0	22.8	12.8	1.2	0.9	1.0
O18	51.8	57.8	28.6	26.0	19.6	16.2	29.8	23.6	2.3	0.6	1.6
O19	54.4	60.2	29.0	25.8	16.6	14.0	27.8	21.8	2.9	0.7	1.4

The general area from which the soil samples were selected ranged from the northern fringe of the brown soils at Penticton to the southern fringe of the black soils at Oyama. It was anticipated, therefore, that the organic matter content would increase from Penticton north to Oyama. An examination of the data has not revealed any such trend. The effects of climate have apparently been masked by the effects of 30 years or more of irrigation, cover cropping, cultivation, and soil erosion.

The usual effects of depth of soil on organic matter content were found. In other words, most of the organic matter was found in the surface 8 inches, and progressively less at the lower depths. A few examples are presented in Table 2.

TABLE 2.—EFFECT OF SOIL DEPTH ON ORGANIC MATTER CONTENT

Plot No.	Soil texture	Organic matter content		
		0 to 8*	8 to 24*	24 to 60*
P2	Silt loam	2.9	1.3	0.9
P10	Sandy loam	1.2	0.7	0.7
K18	Clay	3.2	2.5	0.7
K1	Sandy loam	1.4	0.2	—
G20	Clay	3.9	2.5	1.6
G50	Sandy loam	1.7	0.8	0.5
W9	Clay loam	3.8	2.6	1.3
W4	Loamy sand	0.8	0.4	0.1

* Depth of soil in inches.

A preliminary examination of the data indicated that the heavier soils contained more organic matter than did the lighter soils. This is illustrated by the four pairs of soils listed in Table 2, one of each pair being a heavy soil and one a light soil. The correlation between the colloid contents and the organic matter contents of the 0 to 8 inch samples of the 74 plots was determined, and found to be +0.653, which was "highly significant" (odds greater than 99 : 1). In other words, there was a tendency for the organic matter to increase as the soil became heavier. In confirmation of this, the correlation between the moisture holding capacity and the organic matter content of the 0 to 8 inch samples was +0.777 and that of the 8 to 24 inch samples was +0.834. Both of these are likewise "highly significant".

The question arises as to whether the high correlations between organic matter content on the one hand and the colloid content and moisture holding capacity on the other hand might be due to the effects of the organic matter content on the other two factors. In other words, the presence of the organic matter will automatically increase both the colloid content and the moisture holding capacity. In order to check up on this, that portion of the moisture holding capacity that could be attributed to the organic matter content was estimated, using 179% as the moisture holding capacity of organic matter. This was based on Olmstead's (7) figure for the normal moisture capacity of organic matter. As an example of the calculation involved, the organic matter content of sample P2 (0 to 8

inches) was 2.9% and that part of its moisture holding capacity due to this organic matter was approximately $2.9 \times 1 \cdot 79 = 5.2\%$. The amounts thus calculated were deducted from the moisture holding capacities (14). The correlation between these residual moisture holding capacities and the organic matter contents was then calculated, and found to be +0.465 for the 0 to 8 inch samples. This is distinctly lower than the original figure of +0.777, but is still "highly significant". It appears from this that there was a strong tendency for the heavier soils to have higher organic matter contents than the sandier soils. The reason for this was not ascertained. It was suspected, however, to be due to at least the following two causes: *(a)* better growth of cover crops on the heavier soils, resulting in a greater accumulation of organic matter, and *(b)* greater erosion of the sandier soils, resulting in a greater loss of organic matter.

Included in the 74 McIntosh plots were three series of plots in controlled fertilizer experiments. In these three series, the application of fertilizers containing nitrogen increased the organic matter content above that in the plots receiving no fertilizer, but the addition of phosphate and potash brought about no further increase.

The organic matter content of the soil was correlated with the average terminal length of the trees over a period of 6 years (13). Using the organic matter content in the 0 to 8 inch depth, the correlation was −0.007; and using the organic matter in the 0 to 24 inch depth, the correlation was +0.103. These figures are both "non-significant". In other words, there is no evidence of any relationship between the organic matter content of the soil and the vigour of the trees as represented by terminal length.

Similar correlations were calculated between the organic matter content in the 0 to 8 inch and the 0 to 24 inch depths respectively and the yield of fruit per acre. The yield figures use in making these correlations were those that had been adjusted for differences in size of tree (13). The 0 to 8 inch correlation was +0.094, and the 0 to 24 inch correlation was +0.245. This latter figure is "significant" (odds between 19 : 1 and 99 : 1). In other words, there is some evidence of an increase in yield accompanying an increase in organic matter.

The question arises as to whether this increase in yield is due to the presence of the organic matter, or whether it is due to some other factor. In an attempt to determine this, the correlation between the organic matter content of the soil (0 to 24 inch) and the yield of the trees was re-calculated, using a partial correlation to eliminate the effects of differences in soil texture, as represented by the moisture holding capacity. The resulting correlation was −0.089. The process was then repeated, using the net moisture holding capacity after deducting that portion attributable to organic matter. A correlation of +0.123 was obtained. Neither of these correlations is "significant". There is thus no proof of any relationship between the organic matter content of the soil and the yield of the trees.

DISCUSSION

Although no proof was obtained from this investigation that organic matter in the soil has a beneficial effect on the growth or yield of tree fruits, it cannot be assumed that there is no such effect. As pointed out by

Cummings (3), the beneficial effects of organic matter may accrue not so much from its mere presence in the soil as from its rate of "turnover". In other words, the decomposition of the organic matter is accompanied by improved bacterial conditions in the soil. The decomposition products, in turn, induce a more rapid breakdown of the insoluble inorganic material. The nature of the organic matter present, its rate of decomposition, and its effects on the chemical and bacterial status of the soil, are not measured by a mere determination of its quantity at any one time.

Another difficulty encountered in this investigation is that other factors than the organic matter content of the soil were active in limiting growth and yield of the trees. By way of example, there was the nitrogen content of the soil. In a high percentage of the plots, both growth and yield were limited by a deficiency of nitrogen. Moreover, this deficiency was in some cases accompanied by a relatively high content of organic matter in the soil, a situation obtained when a permanent grass sod cover crop was grown and an insufficient amount of nitrogenous fertilizer was applied.

Although it has been adequately demonstrated by soil investigators that organic matter benefits the soil in a number of ways, it does not necessarily follow that a high organic matter content is essential to normal crop production. In this present investigation, for example, high yields were obtained from trees in soils whose organic matter contents could not be considered exceptionally high. Plot G26 averaged 1526 loose bushel boxes per acre per year for the 6-year period, yet its soil contained only 1.2% of organic matter in the top 8 inches. The figures for P lot G42 were 1602 boxes and 1.7%; for P lot K24, 1509 boxes and 1.3%; for P lot P9, 1813 boxes and 1.8%; and for P lot P10, 1950 boxes and 1.2%. It is cases like this that have helped to lower the correlation between the organic matter content of the soil and tree yield.

On the other hand, many cases of obvious organic matter deficiency have been encountered. In some of the non-irrigated orchard areas in the southern interior of British Columbia (not covered in this investigation), the rainfall has not been heavy enough to allow the growing of cover crops. Furthermore, stable manure and straw have been expensive, and have been sparingly used. Much of the soil, accordingly, has become too low in its organic matter content. This has resulted in a heavy run-off of the rain or melting snow, especially on silt and clay soils, and all types of soil are now subject to severe surface erosion. Such a condition is seldom encountered in the irrigated areas, where it is a common practice to grow cover crops.

SUMMARY

The organic matter content was determined in soil samples from depths of 0 to 8 inches, 8 to 24 inches, and 24 to 60 inches, obtained from 74 plots of mature McIntosh apple trees. Mechanical analyses were also made.

Within the climatic range of the plots, from the northern fringe of the brown soils to the southern fringe of the black soils, no measurable effect of climate on organic matter content was found.

The organic matter content decreased with depth in the soil. It was higher on the average in the silt and clay soils than in the sandy soils. It was increased by applications of nitrogenous fertilizers, but not by applications of fertilizers containing phosphate and potash.

No relationship was found between the organic matter content of the soil at any one time and either tree growth or tree yield.

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THE OCCURRENCE OF NEW STRAINS OF *PUCCINIA TRITICINA* IN CANADA AND THEIR BEARING ON VARIETAL REACTION[1]

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INTRODUCTION

With the distribution through much of the spring wheat area in the United States and Canada of Thatcher wheat, leaf rust (*Puccinia triticina* Erikss.) acquired new importance owing to the high susceptibility of this variety to most physiologic races of the rust. Since Thatcher was distributed, a number of hard red spring wheats with more or less resistance to leaf rust have come under cultivation in the same area (*e.g.*, Rival, Pilot, Cadet, Mida, Newthatch, Renown, Regent). The leaf-rust resistance of these and most other recently produced spring wheats was derived from Hope or H-44. As this resistance is manifested to a much greater degree in the adult-plant stage than in earlier growth stages, it is designated as "adult-plant" or "mature-plant" resistance and is accordingly most useful in regions in which leaf rust does not develop until plant growth is well advanced.

For several years after the distribution of wheat varieties with adult-plant resistance it appeared that this type of leaf-rust resistance was highly satisfactory, at least under conditions prevailing in Canada. Varieties such as Renown and Regent rarely showed more than 10 or 15% infection, and losses caused to these varieties were inappreciable. Tests made in the greenhouse in the spring of 1941 indicated (7) that Renown and Regent possessed adult-plant resistance to all of the 19 physiologic races employed, namely, races 1, 2, 3, 15, 20, 27, 28, 29, 31, 34, 39, 44, 52, 58, 71, 83, 89, 104, and 130. As a result of these tests it was concluded that "it seems probable that these two wheats exhibit towards North American races of leaf rust a resistance as general though not as great as the resistance they show to physiologic races of *Puccinia graminis Tritici* Erikss. and Henn."

RECENT PATHOGENIC CHANGES IN LEAF RUST

Although Renown and Regent displayed, in general, a high resistance to leaf rust there occurred now and then isolated instances of an apparent breakdown in resistance. For example, in 1936, Regent (R.L. 975.1) growing in the rust nursery at Ottawa, Ont., bore a 50% infection; and in 1937, Renown (R.L. 716) at Agassiz, B.C., bore a 75% infection while at other stations infections of 30 to 50% were not uncommon. As no unusual physiologic races were detected in connection with these outbreaks, the severity of infection was attributed to the influence of environmental conditions.

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Despite such sporadic evidence of breakdown in the leaf-rust resistance of Renown and Regent, little concern was felt for their rust reaction until the summer of 1943 when Regent, Renown, and other derivatives of Hope and H-44 rusted severely in the field plots at Winnipeg under conditions of an artificially induced epidemic in which all available physiologic races were present. In the same summer, severe infection of Regent and Renown (60 to 80%) was recorded in uniform rust nurseries at Ottawa and Manotick, in eastern Ontario.

As the physiologic races isolated from these 3 localities were also generally present in other localities where no breakdown in resistance occurred, it was again concluded that unusual environmental influences had affected varietal reaction—an inference that seemed reasonable in view of the fact that the severe infection was present chiefly on grain sown unusually late.

In the summer of 1945, there was for the first time evidence of a widespread breakdown in the leaf-rust resistance of Regent and other varieties with similar reaction (*vide* Tables 1 and 2). Throughout Manitoba and eastern Saskatchewan, and in many localities in Eastern Canada, Regent reacted like a moderately susceptible variety. At the same time there was a sharp increase in the number of isolates of physiologic race 128, a race that, at least under the greenhouse conditions prevailing at Winnipeg, is scarcely distinguishable from race 29. Race 128 was first identified, in Canada, in 1944. In that year, it made up 11.8% of all leaf rust isolates and in 1945 this rose to 26.1%. However, this race was, undoubtedly, less prevalent than is indicated by the above percentages because many collections were made on varieties that tended to select out this race. The most notable feature of the physiologic race survey of 1945 was the fact that race 128 accounted for no less than 66% of the isolates derived from Regent, Renown, and Coronation (a variety with adult-plant resistance widely grown in Eastern Canada).

TABLE 1.—AVERAGE PERCENTAGES OF LEAF RUST ON REGENT (R.L. 975.6) AND THATCHER (R.L. 1246) IN UNIFORM RUST NURSERIES IN CANADA, 1940 TO 1945. (ONLY THOSE STATIONS ARE INCLUDED IN WHICH MORE THAN A TRACE OF LEAF RUST WAS PRESENT ON REGENT)

Year	1940	1941	1942	1943	1944	1945
No. stations	7	12	12	12	15	21
	%	%	%	%	%	%
Regent	9	9	12	24	17	52
Thatcher	64	60	86	82	67	85

TABLE 2.—AVERAGE PERCENTAGES OF LEAF RUST ON WHEAT VARIETIES IN CO-OPERATIVE TESTS AT WINNIPEG, MORDEN, AND BRANDON, MANITOBA, 1942 TO 1945

Year	1942	1943	1944	1945
	%	%	%	%
Regent (R.L. 975.26)	10	19	15	52
Regent × Thatcher (R.L. 2038)	9	19	13	54
Cadet (R.L. 1597)	7	14	17	51
Newthatch (R.L. 2752)	—	19	26	52
Regent (R.L. 975.6)*	10	28	40	80
Thatcher (R.L. 1246)	67	75	64	79

* Percentages from uniform rust nurseries at same stations but sown later.

At this point, a discussion of the relationship between races 29 and 128 is advisable. Race 29 had been identified from field collections annually since 1937 but was regarded as of minor significance for 2 reasons. First, it occurred relatively infrequently; and second, it was no more virulent on Renown and Regent than other races (7). In 1944, race 128 was identified for the first time but the reactions of the differential hosts to this race and to race 29 were so similar that there was frequently some hesitation as to whether a particular culture should be identified as one race or the other. In that year, race 29 made up 7.7% and race 128, 11.8% of all isolates—a combined total of 19.5%. In the leaf rust survey of 1945, similar difficulties were experienced in distinguishing the 2 races. Because of these difficulties, all cultures suspected of being one or the other of these 2 races were provisionally designated as race 29/128. Owing, however, to the frequent occurrence of this pathogenic type of rust in collections made on Renown and Regent, many of the isolates so designated were kept for infection tests with adult plants of Regent wheat.

In these infection tests, performed in the greenhouse from November, 1945 to March, 1946, it was found that 14 of 18 cultures of the race group designated as 29/128 infected Regent so severely that this variety had to be regarded as completely susceptible, whereas 4 cultures infected it rather lightly (Table 3). It seemed reasonable, therefore, to suppose that the 4 cultures that attacked adult Regent plants lightly corresponded to the race 29 collected in former years, whereas the 14 cultures that attacked Regent plants severely represented a pathogenic strain uncommon in former years. This latter strain was regarded as race 128 because that race was first identified at a time when Regent wheat was apparently losing much of its former resistance; but, owing to the difficulty of distinguishing it from race 29, it might with equal propriety be regarded as a biotype of that race. It was also decided to identify as race 128 those cultures of the race 29/128 group that were not included in the greenhouse tests with mature plants but were collected on heavily infected Regent or varieties with similar reaction.

Table 3.—Pathogenicity of cultures of 14 physiologic races of leaf rust towards adult plants of Regent wheat

Physiologic race	No. cultures tested	No. cultures attacking Regent heavily	No. cultures attacking Regent lightly
2	1	0	1
3	3	0	3
5	5	3	2
9	6	0	6
11	1	0	1
15	11	2	9
29/128	18	14	4
34	1	0	1
58	2	0	2
65	2	1	1
76	4	0	4
101	1	1	0
104	2	0	2
113	2	0	2

Although race 128 was first identified, in Canada, in 1944, there is evidence of its presence at an earlier date. In the above-mentioned tests with adult Regent plants, there was included a culture collected at Morden, Manitoba, in 1943 and at that time identified as race 29. This culture proved highly pathogenic to Regent and therefore must now be assigned to race 128 rather than race 29.

Although race 128 is by far the most widely prevalent strain of leaf rust capable of attacking Regent, it is by no means the only one. Of the races used in the tests with adult plants (Table 3), Regent was attacked heavily by 3 out of 5 cultures of race 5, by 2 of 11 cultures of race 15, and by 1 out of 2 cultures of race 65. It was also attacked heavily by the 1 collection of race 101 used in the tests. It may be mentioned here that the 2 last-named races bear a considerable resemblance to races 29 and 128.

It should be clear from the above discussion that the differential hosts now used for differentiating leaf-rust races are not adequate to indicate to the investigator the pathogenic changes taking place in the rust. The changes that have taken place were not apparent because may of the new strains pathogenic to Regent and related wheats were merely biotypes of races that had been present in past years. It seemed necessary to conduct a search for supplementary hosts that would indicate by their seedling reactions the pathogenicity of the rust towards wheat varieties that are now widely grown. The investigator should be able to tell by means of seedling reactions whether any given culture of rust will attack the adult plants of a given wheat variety of economic importance. The results of tests in which a comparison was made of seedling and adult-plant reaction show that rust cultures that attack Regent, Redman, and Renown heavily in the adult stage cannot be distinguished, by the seedling reaction of Regent wheat, from those that attack these varieties lightly in the adult stage. The reaction of Regent will not serve this purpose because of the rather uniform susceptibility of the seedlings to all cultures used in the test. In both Renown and Hope, however, there was a relation between seedling and adult-plant reaction, both varieties being susceptible in the seedling stage to those cultures that attacked adult plants of Regent and Renown heavily, and moderately resistant (showing X type of infection) to all cultures that attacked Regent and Renown lightly in the adult-plant stage. Hence it is probable that either Renown or Hope may serve as a supplementary differential host for distinguishing cultures that attack adult plants of Regent and Renown severely. The utilization of such a supplementary differential host to distinguish 2 strains that are undistinguishable by the standard differential hosts is not a new development. In Australia, the variety Thew has been used by Waterhouse (8) to distinguish certain strains of leaf rust that produce identical infections on the standard hosts.

RESISTANCE TO NEW PATHOGENIC TYPES OF LEAF RUST

Field observations and greenhouse tests alike indicate that the apparent loss of leaf-rust resistance in Regent wheat also applies to other varieties derived from Hope and H-44. In the leaf rust nursery at Winnipeg, in 1943 and in 1945, the varieties Renown, Cadet, and Newthatch bore approximately the same percentage of rust as Regent and, in general, gave

the same impression of susceptibility. The variety Hope, though not included in the leaf rust nursery, was grown in nearby plots and appeared to be susceptible though perhaps less so than Regent. It would seem, therefore, that the adult-plant resistance of Hope, H-44, and their derivatives is no longer fully effective, at least in seasons favourable to leaf rust epiphytotics.

Fortunately there are available leaf-rust-resistant wheat varieties that do not appear to have lost any of their resistance with the advent of new strains of the rust and, although these varieties may not in themselves be of commercial value, they are nonetheless valuable for breeding purposes.

Among varieties that in 1943 and 1945 were grown in the field plots at Winnipeg, and there maintained the high leaf-rust resistance they had shown in previous years, may be mentioned Chinese × Marquis (R.L. 1596), K-33 (R.L. 1885), and Warden × Hybrid English W325. The resistance of Chinese × Marquis and K-33 is confined to the adult plant, the seedling reaction being at least moderately susceptible. The resistance of Warden × Hybrid English W325, on the other hand, is uniformly the same in all stages of plant growth (6, 7).

TABLE 4.—REACTIONS, IN THE GREENHOUSE, OF CERTAIN WHEAT VARIETIES IN THE ADULT STAGE TO PHYSIOLOGIC RACES OF LEAF RUST

Physiologic race	Place of collection	Year	Renown R.L. 716.6	Regent R.L. 975 6	Redman R.L. 1834.1	Hybrid R.L. 2325	Hybrid R.L. 2327	Frontana	Fronteira
3	Lang, Sask.	1945	—	MR	MR	R	R	—	—
3	Fredericton, N.B.	1945	MR	MR	MR	R	R	VR	VR
5	Melita, Man.	1945	S	S	S	R*	R	VR	R
5	Indian Head, Sask.	1943	—	MR	R	R	R	—	—
9	Lacombe, Alta.	1945	—	MR	MR	R	R	—	—
9	Lethbridge, Alta.	1945	MR	MR	MR	R*	R	VR	R
9	Guelph, Ont.	1945	—	MR	MR	R	R	—	—
9	Kapuskasing, Ont.	1944	—	MR	MR	R	R	—	—
9	Morden, Man.	1942	—	MR	MR	R	R	—	—
11	Fredericton, N.B.	1945	MR	MR	MR	R	R	—	—
15	Gordon Head, B.C.	1945	MR	MR	MR	MR	MR	VR	VR
15	L'Assomption, Que.	1945	—	MR	MR	R	R	—	—
15	Duff, Sask.	1945	MS	S	S	R*	R	VR	VR
15	Indian Head, Sask.	1945	—	MR	MR	R	R	—	—
34	Duhamel, Alta.	1943	—	MR	MR	R	R	—	—
58	Ste. Anne de la Pocatière, Que.	1945	—	MR	MR	MR	MR	—	—
58	Fredericton, N.B.	1945	—	MR	MR	MR	R	—	—
65	Scott, Sask.	1944	—	MR	MR	R*	R	—	—
65	Saanichton, B.C.	1945	—	S	S	R	R	VR	R
76	Macdonald College, Que.	1944	—	MR	MR	R	R	—	—
101	Altamont, Man.	1945	S	S	S	R	R	VR	VR
104	Bagot, Man.	1943	—	MR	MR	R	R	—	—
113	Guelph, Ont.	1943	—	MR	MR	R	R	—	—
128	Stockholm, Sask.	1945	—	S	S	R	R	VR	MR
128	Deloraine, Man.	1945	S	S	S	R*	R	VR	R
128	Margo, Sask.	1945	—	S	S	R	R	—	—
128	Souris, Man.	1945	S	S	S	MR	R	—	—
128	Saskatoon, Sask.	1945	S	S	S	R	R	—	—
128	L'Assomption, Que.	1945	—	S	S	R	R	VR	MR
128	Morden, Man.	1943	—	S	S	R*	R	—	—

* Variety not pure—Some plants MR.

Explanation of symbols: VR = very resistant; R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible.

It is evident from recent greenhouse tests that the type of resistance possessed by Warden × Hybrid English W325 is not affected by the presence of strains of leaf rust that have overcome the adult-plant resistance of the Hope-H-44 type. Two hybrid lines, R.L. 2325 and R.L. 2327, derived from the cross [McMurchy × (Warden × Hybrid English W325)] × Redman, made at the Dominion Laboratory of Cereal Breeding, Winnipeg, were tested in the adult stage, in March, 1946, for their reactions to a number of leaf-rust cultures capable of attacking both Regent and Redman heavily. The reactions of the hybrid lines as well as the reactions of Regent and Redman, obtained at the same time, are shown in Table 4. Included in this table are also the adult-plant reactions of Renown and 2 wheats, Frontana and Fronteira, seed of which was recently obtained from the Argentine through the kindness of Mr. A. R. da Silva.

The data presented in Table 4 show clearly that the resistance derived from Warden × Hybrid English W325 is not affected by those races that attack Regent and Redman heavily. In R.L. 2327, where this type of resistance was most clearly manifested, the reaction of the several leaves of the same plant was nearly uniform. Generally, the flag leaf showed small, necrotic flecks and a few, minute, type-1 pustules (Figure 1). On the second and third leaves from the top, flecks were fewer and type-1 pustules more frequent; and on the fourth and fifth leaves, flecks were few and type-1 pustules common and sometimes numerous. Despite the high resistance indicated by the type of pustule present, it is possible that the sharp necrosis

FIGURE 1. Leaf rust infection produced by race 128 on uppermost leaves of adult plants of 2 wheat varieties.
Left—Hybrid line (R.L. 2327) of the cross [McMurachy × (Warden × Hybrid English W325)] × Redman.
Right—Regent (R.L. 975.6).

surrounding the pustules might cause appreciable damage to heavily infected plants. Under exactly the same greenhouse conditions, Regent and Redman showed towards races to which they were susceptible in the adult stage a uniform susceptibility on the different leaves of the same plant. Towards races to which they were resistant in the adult stage they manifested a gradation of reaction: high resistance (flecks and type-1 pustules) on the flag leaf, moderate resistance (2 or X type) on the second and third leaves, and moderate susceptibility (type-3 pustule) on the fourth and lower leaves.

Frontana and Fronteira showed in the adult stage an even higher resistance than did R.L. 2327 (Table 4). In Frontana, this resistance was so great that it approached immunity—numerous small necrotic flecks but few pustules being present. The resistance of these varieties to the cultures that attacked Regent heavily appeared to be much the same as to the other cultures. Reactions of Frontana seedlings to the same cultures showed that seedling resistance in this variety is definitely of a lower order than that of the adult plant. Whereas adult-plant reaction in this variety was in all cases classed as very resistant, seedling reaction varied from resistance (to races 3 and 15) to moderate resistance (to races 9 and 128). Insufficient seed of Fronteira was available to allow this variety to be tested in the seedling stage to individual races; but a single test with a mixture of several races indicated a moderately susceptible seedling reaction.

Tests that have been carried out thus far at Winnipeg, on the seedling reaction of wheat varieties, do not indicate that there are many varieties of *Triticum vulgare* that have general resistance to the physiologic races now prevalent in Canada. Out of 30 *vulgare* varieties tested in the spring of 1945 for their reaction to races 1, 3, 5, 6, 9, 15, 65, 76, 104, 113, 126, and 128, only one variety, Warden × Hybrid English W325, possessed high resistance to all the races. In the spring of 1946, more than 40 other varieties belonging to several species of *Triticum* were tested to 29 leaf-rust cultures, mostly 1945 collections, comprising races 5, 9, 15, 58, 76, and 128. Of the 22 *vulgare* wheats used only one, the Argentine wheat La Prevision 25, displayed high resistance to all of the cultures. No tests have been carried out with adult plants of this variety but presumably it is resistant also in the adult stage. Of the non-*vulgare* wheats included in the tests, the following showed high resistance to all of the leaf-rust cultures: *T. monococcum* var. *flavescens* (2 strains, one of which was the named variety *Einkorn*); *T. turgidum* var. *mirabile; T. polonicum* var. *Halleri; T. durum* var. *libycum;* and *T. aegilopoides.*

EFFECT OF TEMPERATURE ON VARIETAL REACTION TO LEAF RUST

Not the least among the considerations to be taken into account in evaluating the importance of any particular type of leaf-rust resistance is its stability with regard to the environment in which the plant is growing. Conditions of temperature, moisture, and light undoubtedly influence, to a certain extent, varietal reaction to leaf rust. As temperature is thermostatically controlled in certain of the greenhouses of the Dominion Laboratory of Plant Pathology, at Winnipeg, it was possible to test the influence of this factor on leaf-rust development on several wheat varieties with different types of rust reaction.

Of the 7 varieties chosen for the tests, Marquis, McMurachy, and Thatcher are moderately to highly susceptible in all growth stages; K-33, Chinese, and Hope are more or less susceptible in the seedling stage but possess resistance in the adult stage; whereas Warden × Hybrid English W325 is resistant in all growth stages.

Four physiologic races—5, 9, 15, and 76—were used and 2 tests were performed, one in January and one in April, 1943. In both tests, plants were grown to heading under ordinary greenhouse conditions. After inoculation, the plants were placed in two thermostatically-controlled greenhouses maintained at approximately 60° F. and 80° F., respectively—half the plants inoculated with each race of the rust being placed in each greenhouse.

The results of the tests (Table 5) show that varieties susceptible at ordinary temperatures may become resistant at high temperatures. The critical temperature for the induction of resistance in a susceptible variety appears to be slightly above 80° F.; earlier experiments (3) had indicated a temperature of 85° F. or higher. It is likely that the exact temperature level at which this change takes place is influenced by other factors in the environment. It is perhaps worthy of note that the temperature level at which McMurachy wheat became resistant to leaf rust is almost exactly that at which it has been shown to become susceptible to stem rust (5).

The reactions of Hope and Chinese wheats were less stable than that of the other variety with adult-plant resistance, *i.e.* K-33. Conditions other than temperature may have exerted an influence as both Hope and Chinese were more resistant in the April test than in the one performed in January. Possibly the conditions of daylight in the April test were more conducive to the development of resistance than the poorer light conditions of the January test. If so, the influence of light on the leaf-rust reaction of Hope and Chinese is much the same as on the stem-rust reaction of Hope (2, 4) which is most susceptible under conditions of short day and diffuse light.

The reaction of Warden × Hybrid English W325 was influenced very little by temperature or by the different conditions of light prevailing in the two tests.

DISCUSSION

In view of the extensive cultivation in Canada and the United States of wheat varieties with the Hope-H-44 type of adult-plant resistance to leaf rust, the breakdown of this resistance would be a matter of considerable economic importance. There is not yet sufficient evidence to state categorically that this type of resistance will no longer be effective in future years. It must be admitted, however, that varieties with this type of resistance gave the impression of moderate susceptibility in 1945 in Manitoba and eastern Saskatchewan.

The future reaction to leaf rust of such varieties is a matter of conjecture because it is not known whether the new pathogenic strains will persist in coming years nor is it known whether the loss of resistance in these varieties in 1945 was due entirely to the presence of these strains of the rust or was in part due to environmental effects. It may be that these varieties will rust severely only in years in which conditions are particularly favourable to leaf rust development, but it should be noted

TABLE 5.—REACTION, IN GREENHOUSE TESTS, OF 7 WHEAT VARIETIES TO 4 PHYSIOLOGIC RACES OF LEAF RUST AT DIFFERENT TEMPERATURES

Variety	Time of test	Temp. °F. (Mean)	Race 5		Race 9		Race 15		Race 76	
			Adult	Seedling	Adult	Seedling	Adult	Seedling	Adult	Seedling
K-33 (R.L. 1885)	Jan.	77	R	MS	R	MR	I to R	MS	R	R
		59	I to R	MS	I to R	MS	I to R	MS	R	MS
	Apr.	82	R	—	I	—	R	—	R	—
		61	R	—	R	—	R	—	R	—
Chinese (R.L. 1815)	Jan.	79	MR to MS	MR	MR	MS	MR	MS	MR to MS	MS
		58	MR	MS	R	MS	MR	MS	MR	MS
	Apr.	82	R	—	I to R	—	R	—	R	—
		61	MR	—	I to R	—	MR	—	MR	—
Marquis (R.L. 84)	Jan.	78	MS	MS	R to MR	MS	MS	MS	MS	MR
		58	MS	MS	MR	MS	MS	MS	MS	MS
	Apr.	82	R	—	I to R	—	R	—	R	—
		61	MR	—	R	—	R	—	MR	—
Warden × Hybrid English (R.L. 1803)	Jan.	78	I to R	R	I to R	I	I	I	I to R	R
		58	I to R	I	I to R	I	I	I	I to R	R
	Apr.	82	I to R	—	I	—	I	—	I	—
		61	I	—	I	—	I	—	R	—
McMurachy (R.L. 1313)	Jan.	79	MS	MS	MS	MS	MS	MS	MS	MS
		57	MS	MS	MS	MS	MS	MS	MS to S	MS
	Apr.	82	R	—	R	—	R	—	R	—
		61	MS	—	MS	—	MS	—	MS	—
Thatcher (R.L. 1945)	Jan.	79	MS	MS	MR	MS	MS	MS	MS	MS
		58	MS	S	MR to MS	MS	MS	MS	MS	MS
	Apr.	82	R	—	I to R	—	R	—	R	—
		61	MS	—	R	—	MS	—	MS	—
Hope (R.L. 209)	Jan.	83	MR to MS	MS	MR	MS	MR to MS	MS	MR to MS	MS
		58	MR	MR	MR	MR	MS	MS	MR	MR
	Apr.	82	R	—	I to R	—	R	—	R	—
		61	I to R	—	I to R	—	MS	—	R	—

Explanation of symbols: I = immune; R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible.

that Regent and Renown wheats now show complete susceptibility in the greenhouse to some strains of the rust while they still retain their usual moderate or even high resistance to other strains under identically the same environmental conditions. Although greenhouse infection tests can never be accepted as an exact index of field reaction, this fact suggests strongly that the susceptibility of these varieties in the field is due to the presence of pathogenic strains adapted to them rather than to environmental conditions.

As far as it is possible to judge from greenhouse and field tests at Winnipeg, it would seem that the leaf-rust resistance of Warden × Hybrid English W325 is unaffected by the new rust strains highly pathogenic to Regent. If so, this variety will have definite value to plant breeders concerned with the development of leaf-rust-resistant wheats. In view of the great variability in the pathogenicity of leaf rust it is probably too much to expect this variety, or perhaps any other, to remain resistant indefinitely. Recent information from South America (1) shows Warden × Hybrid English W325 to be susceptible to physiologic race 5, presumably a collection of it made in the Argentine. This is further evidence of the presence of biotypes in races of the leaf-rust organism, as the Warden × Hybrid English W325 type of resistance has proved highly effective against Canadian collections of race 5 (Tables 4 and 5).

The infection tests with adult plants of the varieties Frontana and Fronteira and the seedling tests with the South American wheat La Prevision 25, indicate further possibilities for the breeding of leaf-rust-resistant wheats suitable to Canadian conditions. Though no infection tests have been made with adult plants of La Prevision, it is probable that its resistance in the adult stage is at least equal to its resistance in the seedling stage. That this variety may possess resistance to many physiologic races is suggested by a report from the Argentine (1) that it proved resistant to the 6 races to which it was tested, namely, races 5, 20, 49, 57, 62, and 114. This variety may prove of some value as breeding material for the production of leaf-rust-resistant spring wheats.

In conclusion, it must be emphasized that in view of the pathogenic changes that have obviously been taking place in leaf rust in recent years it is imperative that adequate annual surveys be conducted to determine the physiologic races present each year. Not only must these races be identified but it is equally essential that a study be made of their pathogenicity towards varieties now in cultivation and, further, that a search be made for resistant wheat varieties that may serve as breeding material in case the need for such arises.

SUMMARY

It has been shown that there are now present in Canada strains of leaf rust that are capable of heavily attacking Regent wheat and other varieties with similar reaction to this rust. Some of these strains must be regarded as biotypes of known races such as races 5 and 15 but the one most commonly present is identified as race 128. This race bears a close resemblance to race 29, which has been found in Canada annually since 1937, but differs by its ability to rust Regent, Renown, and Redman severely in the adult-plant stage. Race 128 was first identified, in Canada, in 1944 when it

comprised 12% of all leaf rust isolates, but there is evidence of its presence in the preceding year. In 1945, this race comprised 26% of all leaf rust isolates and 66% of those derived from Regent, Renown, and Coronation.

The presence of the above-mentioned strains of leaf rust appears to be the chief reason for the severe outbreak of this rust that occurred in 1945 on Regent and other wheats with similar rust resistance. It probably also accounts for sporadic outbreaks of leaf rust on these varieties in the 2 preceding years.

The new strains of leaf rust that seem to have overcome the resistance of Regent wheat have not affected the resistance of certain other wheats particularly K-33, Chinese × Marquis, and Warden × Hybrid English W325. Hybrid lines derived from the cross [McMurachy × (Warden × Hybrid English W325)] × Redman show rather high resistance to all leaf-rust races to which they were tested, including strains of the rust capable of attacking Regent and Redman severely. The South American varieties Frontana, Fronteira, and La Prevision 25 also proved highly resistant to all leaf-rust strains to which they were tested.

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TRENDS IN THE DEVELOPMENT OF AGRICULTURAL ECONOMICS IN CANADA[1]

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GROWTH OF AGRICULTURAL ECONOMICS

Agricultural Economics as an organized activity in Canada traces its origin at least to the period of the first world war. At that time certain of the Colleges of Agriculture undertook both research and instruction in what was then a comparatively new field. During the middle and late 1920's several additional institutions established departments of agricultural economics or added courses of instruction in the subject, to the program of other departments. During this period, too, the Dominion took steps to organize for economic research in the field of agriculture. It is with the developments that have occurred since the late 1920's, and more particularly with activities in the Dominion field, that this paper will deal.

EARLY DEVELOPMENTS

The Agricultural Economics Branch of the Dominion Department of Agriculture was established in 1929 but during the two or three years preceding this development there had been considerable discussion, both official and unofficial concerning the work that should be undertaken by the new unit. Reference to this may now be of interest. It may suggest how far we have progressed in our thinking in twenty years.

The minister of Agriculture of that day, Hon. W. R. Motherwell, had urged as early as 1927, the formation of a "Co-operative Branch" as an addition to the Dominion Department of Agriculture. In reference to the matter in 1928 he had referred to the proposed unit as the "Agricultural Co-operative Marketing Branch". Later the term "Agricultural Co-operative Marketing and Farm Economics" was considered. However, at the suggestion of persons with whom the matter was discussed, including officials of provincial departments of agriculture and leaders in the co-operative movement a much wider field of activity was decided upon than was originally intended. The name chosen for the new unit was "Agricultural Economics Branch". Even then, however, the title "Farm Economics including Agricultural Co-operative Marketing" appeared for some years in the Department's estimates as submitted to parliament.

The decision to reverse the order of emphasis and to enlarge upon the scope of activities to be undertaken may have been influenced by a quotation brought to the attention of the Minister. This was from a statement by

[1] A paper delivered at the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

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Sir Henry Rew, K.C.B., entitled "The Scope of Agricultural Economics", and was published by the Agricultural Economics Society of England about 1928. Sir Henry, in referring to the appointment of Committees by the Imperial Agricultural Research Conference, said:

> "A number of specialist committees were appointed and among them was one to consider 'Agricultural Economics (including Marketing)'. One wonders what conception of the scope of Agricultural Economics was in the minds of those who thought it necessary to explain that it included marketing. It would have been just as reasonable to have explained that the subject included production. Indeed, the sale and distribution of farm products constitute the main part of Agricultural Economics. Subsistence farming comes, it is true, within the range of the subject, but the chief problems of Agricultural Economics arise in connection with commodities which are produced for market. The play of 'Hamlet' without the Prince of Denmark would be a model of coherence compared with a study of Agricultural Economics which excluded marketing".

Those familiar with the development of Agricultural Economics as a science will appreciate that the relationship of subject matter outlined by this British authority is the one generally accepted in countries where economic research has received important recognition. It is the relationship in effect for many years in the United States Department of Agriculture where the Bureau of Agricultural Economics has played an important role.

Nevertheless, in Ottawa the thinking of the Minister, his long association with the co-operative movement and his original desire that co-operation should be featured was reflected in an outline of proposed activities prepared by the present speaker soon after his appointment as Head of the Branch. This outline listed the fields of activities to be dealt with in the following order (1) co-operative marketing, (2) marketing, (3) farm management and economic surveys, (4) land economics, (5) rural sociology, (6) historical research, (7) a current publication.

In 1930 a statement of the activities of the Agricultural Economics Branch was presented to the Canadian Society of Technical Agriculturists, Wolfeville, N.S.[1] In this statement the various fields of research were outlined in this order (1) Farm Management, (2) Land Problems, (3) Credit Finance and Taxation, (4) Transportation, (5) Marketing, (6) Agricultural Co-operation, (7) Statistics, (8) Agricultural History, (9) Rural Sociology. The order of presentation was not intended to suggest degrees of importance but rather that work should begin with the farm and from there proceed to the market and then to the broader field involving the relationship of farmers to the rest of society.

The Thirties

It was on this basis that the program of the Economics Branch (now the Economics Division, Marketing Service) was projected during the decade of the thirties. With the assistance of other Branches or Divisions of the Dominion Department, and in co-operation with the provinces a

[1] Federal Activities in Agricultural Ecnomics: J. F. Booth, Commissioner of Agricultural Economics, Department of Agriculture, Ottawa. A paper presented at the Annual Meeting of the Canadian Society of Technical Agriculturists, Wolfeville, N.S., June 1930.

considerable amount of research was undertaken. Farm and ranch management surveys were among the first projects launched. The Department had committed the Branch to one such survey before even the Order in Council establishing the new Branch was passed.

To the research work in farm management there was added in succeeding years considerable research dealing with land use and land settlement. Land use and the economic classification of land came into prominence in Saskatchewan and Alberta where in co-operation with the Universities, and with funds provided by the Prairie Farm Rehabilitation Administration an effort was made to assist in the solution of the problems occasioned by drought. Some thirty million acres of land have been given an economic classification under this program.

Research in land settlement was suggested by the "Back to the Land" movement of the early 1930's and the belief that there could be recurring interest in settlement as long as land was available for homesteading. A considerable fund of information on the problems of the fringe area from New Brunswick to British Columbia—the cost of establishing a farm, the number of years between settlement and self sufficiency, the size of unit and area of cultivated land required—has been accumulated.

Several years ago a start was made in co-operation with the Farm Management Department, University of Saskatchewan, on a study of land tenure problems. There will be a reference to this angle.

Parallelling the early developments in farm management, plans were worked out with the provinces and the co-operative associations across Canada for the accumulation of statistics on co-operation. The collection and dissemination of information on this subject has constituted one of the important services of this Division. Records are now maintained of the activities of more than 2,000 associations marketing farm products or handling farm supplies—considerable information is also available in the Division on the affairs of a large number of organizations concerned with credit, insurance and other matters. Research based upon these records and upon more detailed field surveys has been conducted from time to time.

In other fields of marketing attention was turned to the costs and margins entailed in the processing and distributing of farm products. The cost of manufacturing cheese and butter, and of wholesaling fruits and vegetables; the returns received from the export sale of apples, the relative merits of selling livestock direct to packers compared with sale through stock yards were among the various projects undertaken at this stage.

The work in marketing included special studies of various city markets —Montreal, Toronto, Ottawa, Quebec and others—in co-operation with provincial and municipal authorities and as a basis for reorganization of the outmoded facilities now found in our older cities. The war interfered with reorganization plans but recent developments in Toronto and Montreal indicate that the matter is still a live issue.

From marketing it is but a step to consumption. With a depression settled on the country, with prices disastrously low and consumer demand anything but active, the decision to enquire into the consumption of farm products will be understood. The original purpose of such studies was

primarily to provide information that would enable marketing agencies to sell more farm products—to get rid of "the surpluses" of that period. It soon became apparent, however, that the information obtained had another and perhaps more important value—that of serving as a basis for improved dietary and health standards.

Some progress was made in other fields too. Studies of rural taxation in Ontario, and of the experiences of the Saskatchewan Farm Loan were major activities in the realm of farm finance.

The enumeration of these typical studies indicate the type of research that characterized the work of the Division during the decade ending in 1939. The establishment of offices at the Universities of Saskatchewan and Alberta and the extension of co-operative relationships with other Universities, Departments of Agriculture and various public bodies, was a prominent feature of the development of this period.

During this decade a conscious effort was made to build up factual information and to tackle the problems of agriculture as near their source as possible. To that end close contacts were established with the farm organizations and much of the work done was at the request of these bodies. To some it may have appeared that the Division was concerned too much with the practical day to day problems of the individual farmer and too little with the broader considerations involved in the determination of agricultural policies.

The War Period

Then came the war and with it a change in emphasis as far as the work of the Economics Division was concerned. As guidance in the field of production and control in respect of the distribution and sale of farm products became necessary, information as a basis for policies, and assistance in developing such policies became essential. Under these conditions a new use was found for the information accumulated by the Economics Division. The data on costs of producing apples in Nova Scotia and the information on prices received in the British market over a seven year period—two of the studies completed during pre-war years—provided a basis for the program of government assistance to the apple industry when access to the United Kingdom market was cut off. So essential was this information that at the request of administrative authorities similar studies dealing with costs of production and distribution in British Columbia were undertaken in 1940.

Similar information with respect to other products was made available and served a purpose in respect of subsidy and price policies, and in connection with farm labour, farm machinery and other matters. The machinery built up, and the research done in connection with the Agricultural Outlook Program carried on from 1935 to 1939 served as a foundation for the development of Agricultural Objectives in 1942 and subsequent years.

The personnel of the Division, with the experience gained in dealing with the economics of production and marketing, was drawn upon by the various Boards and other agencies established to administer the war program. Members of staff were loaned "for the duration" to the British

Purchasing Commission, the Wartime Prices and Trade Board, the Department of Labour, the Reconstruction Committee, the Agricultural Supplies Board, the Agricultural Food Board, the Meat Board and other bodies.

Formal research on the pre-war standard was reduced to a minimum and informal research, if such it may be called, was increased. The sort of research involved in getting quickly the necessary factual information required for the formulation and administration of policies became the principal activity of a substantial proportion of the Division staff during this period.

It may be of interest to note that despite emphasis on matters concerned with the war and the use of economic information in that connection, other activities were carried on and the information obtained by the Division prior to the war was used for other than war purposes. Examples of this were the use of land classification techniques and data by the Commission engaged in the re-assessment of Saskatchewan land and the incorporation of irrigation survey information in the report of the Commission appointed to consider the development of the St. Mary's and Milk River Irrigation project in Southern Alberta.

THE FUTURE

The foregoing outline of developments during the inter-war and war periods, though more lengthy than desired, will, it is hoped, have laid a foundation for consideration of probable developments in the years ahead. Looking back over the changes that have taken place one gets a hint of what is in store for the future. The experiences of the past year in particular throw light on future probabilities.

VARIETY OF WORK

First it may be said that little if anything in the program already in effect can be discarded. Practically every type of activity carried on before the war is represented in requests for additional research made to the Division by farm organizations, distributor groups, provincial governments and similar bodies during the past year or two. As evidence of this the following list of projects and the agencies proposing them are cited: A study of taxation in Prince Edward Island requested by the Government of the Province; an extension of the Toronto Market survey requested by the Ontario Department of Agriculture to bring information obtained before the war up to date and to serve as a basis for market reorganization; a survey of the cost of producing milk in the Fraser Valley of British Columbia, a joint appeal by the Province, the University, Farm organizations and the trade; a study of rural credit by the Saskatchewan Government and surveys of the marketing of fruits and vegetables and of poultry products by the same government; extension of land use and settlement projects in British Columbia; inauguration of farm management and land classification research in southwestern Manitoba requested by the University of Manitoba; special studies of agricultural co-operation in Ontario and British Columbia sought by the farm organizations of these provinces; a survey of the Winnipeg market for fruits and vegetables proposed by the Province of Manitoba.

These requests for research are not made out of idle curiosity or with the desire to get something for nothing, to wit the expenditure of Federal funds in the provinces. They are made with the knowledge that the usual policy of the Economics Division is to require the active participation and expenditure of funds by the province or the University, and the conduct of the project on a joint basis. In the case of one of the projects listed above, trade organizations offered to share the cost. This is evidence of a keen desire to have research undertaken, for it is not usual for organizations or groups other than bodies financed by public funds, to offer financial assistance for the conduct of such research.

One of the most significant requests in connection with post-war programs was that made to the Dominion Committee on Reconstruction several years ago. It was made by the Deans of three agricultural colleges and it urged that one of the most pressing needs was for more work in farm management.

The program of the future must include most if not all of the kinds of activity carried on in the past and on a more comprehensive basis than heretofore. Of that there is little doubt; but it must also go further. In most respects the new developments will be an extension of what has already been done but in some fields virtually new ground must be broken. The new program must continue to emphasize these activities that produce information required by farmers and those engaged in marketing agricultural products—information that can be used by such persons in improving the efficiency of their operations; but it must also yield information needed by farmers as a group and by governments in dealing with agriculture as an industry. The economist will be expected to contribute more extensively to the development of agricultural policies and to general policies that have some relation to agriculture, than was the case before the war.

As evidence of this it may be worthwhile to refer to some of the other requests that have been made of the Economics Division, and to some of the things that are taking place in Canada and beyond our borders.

Projects Under Way

A year or two ago the Province of Alberta appointed a Commission to study the question of rural electrification. There were many angles to be considered—more than just the fact that farmers would benefit from greater access to electricity. The Economics Division of the Dominion Department of Agriculture and the staff of the University were asked to participate in the work of the Commission.

The Economics Division, in co-operation with provincial authorities and with the assistance of farm organizations has recently completed a national survey of probable farm machinery, farm equipment and building material requirements over the next few years. The survey was requested by Dominion authorities as a basis for allocation of materials. Although this project is related to wartime controls it is evidence of the kind of thing that may be anticipated if governments play a more active role in business affairs than in pre-war days.

The Division has also recently completed a survey for the Reconstruction Department—a segment of a more general study relating to reconstruction, public investment and employment.

In Saskatchewan, economists of the Dominion Service together with those of the University of Saskatchewan are participating in the work of a Committee that is considering the more effective use of land within the province. The results of research already completed are being used and new projects will take into consideration the needs of this Committee.

Conservation

Agricultural conservation is not a new subject but it is one that is likely to receive much more consideration in the years to come. Agricultural authorities have in the past been concerned with the matter mainly as a factor in farm operations; at least that was so prior to the passage of the Prairie Farm Rehabilitation Act and the development of a program under its auspices. The subject is now becoming invested with a public interest, and in eastern as well as western Canada. Agriculture will not stand alone in any extension of work in this field. Conservation involves forestry, fisheries and wild life, water power, flood control and the development of parks and recreational areas. In short it concerns the public and public policy in the widest sense. Recent developments suggest that farm economists will be expected to participate in the conservation program of the future on an even more extensive basis than in the past.

Land Tenure

Land tenure is a matter that is likely to call for more consideration in the future. A conference recently held at the University of Chicago, which was participated in by representatives of eleven countries, indicates that on the basis of the experience of older countries we are likely soon to face many questions in connection with land tenure. We already have a hint of this and some research has been conducted. Much more will be required, however.

Marketing and Transportation

There are many new developments in the field of marketing. New processes and new products have emerged as a result of war and recent scientific achievement. Dehydrated products, frozen foods, storage lockers, new processes and facilities for packaging—all these and more, suggest new problems, and new opportunities. Agricultural economists are certain to be called upon to play some part in the development in this field.

The economics of transportation and distribution has received little consideration from agricultural economists to date. With all the changes that are taking place, and with the implications they carry for agriculture, can we stand on the side lines looking on?

Rural Credit

Rural credit is a perennial topic but have we heard the last of it? Evidently not, for the Economics Division has before it for consideration two requests for studies of credit facilities and credit needs. One of these already referred to as coming from the government of Saskatchewan involves credit unions—an agency that as far as this continent is concerned emerged in Quebec 40 years ago, and which during the past decade has spread

rapidly over the whole of the Dominion. Much has been done in recent years to meet the current needs in agricultural credit but the need changes from time to time and economic research will be necessary for the development of future policies.

Food and Agriculture Organization

The fields of nutrition and food management have come to the fore prominently in recent years. No longer does agriculture stand alone pleading for markets for its products. The world has become food and scarcity conscious. As a solution to the problem of surpluses there has been added the conception of a world adequately fed. An international agency, the Food and Agriculture Organization, has been created to encourage world thinking and to co-ordinate international action. FAO is a forward step and much can be achieved by it if nations will but co-operate. It cannot function on pious hopes and prayers, however. There must be action and action must be preceded by careful study. The plans already laid by the organization emphasize research in many fields and the establishment of an economics division is a step in that direction. Canada will be expected to contribute in various ways.

FAO emerged as a product of the war but it is much more than that. It traces its origin to the restrictionist 1930's—to the sectionalism and nationalism that prevailed at that time. It traces its origin, too, to the contrasting conditions of surplus and malnutrition.

FAO is in a sense a symbol of a new order and of new thinking; or should one say a return to order and thinking. In any event, the thinking that brought it into being is also responsible for other important developments in internationalism—in the fields of finance, communication, and trade, to mention but three. These portend important new development and no country or group will be more concerned with what transpires than Canada and Canadian farmers.

Canadian farmers, because of these developments will be more concerned with what is taking place in other countries than ever before. Agricultural departments will be expected to provide a service in respect of foreign agriculture and since most of what takes place will be in the field of economics it is apparent that agricultural economists will be called upon to make their contribution.

Greater Expansion Needed

If this analysis of the situation is correct it follows that there must be an expansion, and to some extent a new emphasis in agricultural economic research and service. It means more consideration of agriculture as an industry, as a segment of a national and international economy. It means more research directed toward the formulation of policies and more help to those responsible for administration. It must not, however, mean less research on the problems of production and marketing which are the immediate concern of the farmer and those who market his product, for were that to follow, it would mean lessened ability to participate in the new order—an order which despite its evidence of freedom, will be characterized by an intensity of competition in trade and in other respects.

It has been said that you cannot tell how fast a horse is running by watching it pass a tree—you must match it with other horses. The application of this to agriculture suggests that we take a look at what is happening elsewhere—what steps are being taken by other countries to meet competition. It will not be possible to dwell at length on these but it can be said that everywhere steps are being taken to increase services on behalf of agriculture. The plan for reorganization and expansion announced last year in Britain is one evidence of this. The existence of a corps of graduate students from South American countries studying in the United States, and studying in particular the organization of the Department of Agriculture, is another. Exchanges from other countries all emphasize a similar development.

Agricultural Education

Not of least significance in this regard is the recognition of agricultural economics. A Committee was appointed in the United Kingdom in 1944, by the Minister of Agriculture and Fisheries, to consider the need "for higher agricultural education" in England and Wales. It recently issued an 85-page report summarizing its findings. In referring to agricultural economics the Committee states:

"We have chosen to deal separately with Agricultural Economics because although the term comprehends a varied range of studies which enter more or less into the functions of all occupational classes that we have discussed, those studies are all concerned in one way or another with a common aspect of agricultural activity, which has received insufficient systematic attention in the past and is likely to claim very much more in the future. Since agricultural economics is concerned with the business side of farming, and farming is essentially a business, the agricultural economist's field is coterminous with agricultural activity. Agricultural economics is in fact the counterpart and complement of the whole group of natural sciences as applied to agriculture. Its scope may be illustrated by mentioning a few of the subjects with which it deals. They include land utilization; types of farming; land tenure, capital, credit and taxation; farm management and accountancy, including measure of efficiency; labour and wages; markets and prices; international trade in farm products; relations between the state and agriculture; rural sociology and agricultural history".

While appointed to consider the need for better training of men in agriculture the Committee by inference and assertion makes it clear that the agricultural services of England and Wales must be both improved and expanded to meet post-war needs. The appointment of such a Committee is in itself evidence of such a belief in official quarters. The prominence and positiveness with which the committee expresses its views on agricultural economics and the business side of farming must be encouraging to those who for years have felt that these matters received too little attention.

Emphasis on Agricultural Economics

Agricultural Economics had attained considerable recognition in the United States, Germany, Holland, Denmark, Sweden, Switzerland, Australia, New Zealand and South Africa before the war. Recent advice from

Australia indicates that the pre-war development has been expanded into the status of a Bureau comparable in rank with other divisions of the agricultural service. In Mexico, Brazil, Argentine, Chile and other Latin American countries Bureaus and Divisions of Agricultural Economics have been established in recent years.

The report of the British Committee to which reference was made refers to Canada as having given more recognition to agricultural economics than has been accorded the subject in England and Wales. While this recognition is gratifying and while it is a matter of much satisfaction that agricultural services including economics are being expanded by the Dominion Government, in one respect at least progress in Canada has not been all that it should have been. Reference is made to work in Agricultural Economics in the provinces. Agriculture is the responsibility of both the Dominion and the provinces under the British North America Act and there are phases of the work in agricultural economics that should be handled by the provinces. Not the least important of these is the training of agricultural economists. It is no secret that one of the things retarding expansion in the Dominion service today is a lack of adequately trained agricultural economists.

The Report to which reference has been made refers to the fact that "every important university in the United States of America has a professor of agricultural economics". This is a characteristic British understatement of fact. Practically all the United States Universities which have agricultural faculties, and some that do not, have several professors of agricultural economics. Some have from 10 to 20 and even more. Applying the comparison to Canada it may be said that at any one of several Universities in the United States there are more agricultural economists than in the nine universities and agricultural colleges of Canada combined. An analysis of the staff at universities in the States bordering Canada alone, made several years ago, indicates that there were at that time 191 persons engaged in agricultural economics and rural sociology. The number at all Canadian universities and colleges was 25, about half of whom were on a seasonal or part-time basis.

It is realized that we should not make too much of what others are doing. It may not be possible for us to do what they are doing, particularly our more wealthy and more populous neighbour. But are we doing what is possible? Do we recognize that very important changes have taken place in the thinking of farmers and in the needs of agriculture and that everywhere people in rural areas want information and help on economic and social problems.

SUMMARY

It is nearly twenty years since the first discussions that led to the formation of the Economics Division of the Federal Department of Agriculture took place. Nearly three years elapsed before the Division was established. They were fruitful years in one sense, however, for in the discussion that accompanied delayed action there emerged a much broader conception of what should be encompassed in the work of such an agency than was originally envisaged.

The Division when established in 1929 embarked upon a fairly comprehensive program of research but one in which the immediate problems of those concerned with production and marketing received primary attention. As the years passed, as services were expanded and as the usefulness of economic information became apparent, some contribution was made toward the solution of problems faced by those responsible for agricultural policies and administration. In the main, however, the years leading up to 1939 were devoted to the accumulation of factual information and to dealing with the day to day problems of farmers and the agencies marketing farm products.

With the advent of war the situation changed appreciably. In the development and administration of numerous policies necessary to a maximum war effort the need for statistical and economic information soon became apparent. The accumulated information of the Division soon became useful, but research activities were necessarily curtailed. Much of what was undertaken during this period was concerned with policies and administration.

The return of peace has brought a renewal of demands for the kind of service provided before the war and on a much broader scale but it has also brought a new demand—an extension in some measure of the activities of the war period. These demands are associated with a greatly enlivened interest in both national and international affairs. Canadian farmers have again become conscious, perhaps more than at any time in Canadian history, of what a world in need of food can mean to them, and they to it. There is hope on the horizon and much of it stems from the creation of the Food and Agriculture Organization, the provision for financing world trade and the prospective formation of an international body to facilitate trade among nations.

In meeting the needs of an agriculture desirous of playing its part in this enlarged sphere of activity there are likely to be opportunities for those concerned with the economics of agriculture to play an increasingly important role.

Finally, while it has seemed appropriate to discuss developments during the past two decades in terms of the experiences of the Economics Division at Ottawa, those familiar with what has happened in the provinces and with what is likely to happen in the future will, it is hoped, recognize in what has been said much that is descriptive of their experiences and of what the future has in store for them.

RESEARCH TRENDS IN AGRICULTURAL ECONOMICS[1]

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Whether the contents of this paper are adequately described by the title allotted on the program is open to conjecture. However, the writer was a member of the program committee and as such has taken the privilege of a rather wide interpretation of what might be included in these remarks. In recent months a number of articles and comments have been published in the Journal of Farm Economics relating to the topic of research. The author wishes to acknowledge these as a general source of some of the ideas which are presented herein.

It is most appropriate that in the field of agriculture generally, and in agricultural economics particularly, the theme of these meetings should be "Research". For the past six years an upheaval has taken place the impact of which on the social, political and physical sciences, is beyond our comprehension at this close range. We are still too close to the events of the immediate past to realize their far-reaching implications in full. Irrespective of our wishes, our feelings, or our failure to appreciate these implications, there will no doubt be general agreement that the ways and means of the twenties and thirties are out of step with modern requirements. Accordingly, we must temper our attitudes and adopt ways and means appropriate to the new circumstances.

PRESENT CONDITIONS

And which of these new circumstances are important to the research worker in agricultural economics? Let us look at some of the developments of the war years which may offer clues to the probable trends in research in the science of agricultural economics. At least three main developments carry suggestion of probable future trends. These developments may be described under the following headings.:

(a) Wartime measures of economic control and support of agricultural activities,

(b) Technological developments of direct and indirect importance to agriculture,

(c) Increased public support of research programs in the physical sciences.

Wartime Measures

Referring to the first mentioned development, namely wartime measures designed to control and support agricultural activities, there will be general agreement that a large proportion of these will continue into the peacetime period. In fact, some of them are already on the statute books as permanent legislation.

This development carries with it a suggestion of greatly increased needs for research in agricultural economics. Control and support pro-

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

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grams for the agricultural industry will be accepted in a democratic society over a long-time period only as long as they can be justified and are operated on grounds which have a reasonable economic basis. Accordingly, continuous research projects will be necessary, designed, first of all, to acquaint those responsible for the programs and the public generally with the effectiveness and general economic justification for continuance of any particular policy. Research of this nature, however, cannot be confined to government sponsorhsip. To provide adequate safeguards, a rather broad program of private research, financed and directed by independent means, will be necessary. In fact, a privately financed and directed program of research in agricultural economics is one of the dominant needs in Canada today. Unfortunately, most of our institutions equipped to do research in agricultural economics are dependent on Dominion, provincial or municipal government sources for their financial support. Let us hope, however, that in the not too distant future some means may be found of providing for independent research and that we shall have private agencies carrying out unbiased and acceptable research programs designed to study not only the impingement of agricultural policy on the agricultural industry but on the Canadian economy in general.

As one interested in the statistical side of research projects, my view is that it would be well for those departments or agencies of government which are responsible for such programs or policies, to give serious consideration to the collection and documentation of statistical data and other relevant information as a source of material for the research worker. Too often in the past, boards, commissions or other agencies have been organized, served their purpose and then disintegrated, only to leave a paucity of information and records which mitigate against an adequate research job. In fact, today some agencies set up to meet special wartime requirements are already being disbanded. In some cases arrangements have been made for taking over and preserving their statistical and other records but even more can be done in this direction.

Not all of the information required for an adequate research program will be available or come from within the department or agency itself. In many cases very valuable and significant contributions will be derived from official government data and from data assembled by private agencies. Aware of the existing and future needs for adequate and reliable information on Dominion, provincial and regional bases, steps have been taken to improve, not only current, but historical statistical series in order that they may be utilized in studies of price-production, demand-supply relations and other like projects. Improvements in statistical series will take time but the benefits, particularly in respect to the matter of forecasting, will more than justify the efforts put into this work. Fundamentally, research programs of this nature will stand or fall upon the adequacy and reliability of the information on which they are based. It is, therefore, most essential, that not only existing statistical data pertinent to research in agricultural economics be improved, but that, as far as possible, future requirements be anticipated some time in advance of the need. Those familiar with statistical series are aware of the necessity for a sufficient period in which to judge the reliability and accuracy of any new series before utilizing these in research programs.

Realizing, of course, that the fact-gathering type of research will continue, nevertheless, we must recognize that there already exists a very considerable amount of undigested material awaiting the research worker. Some of this material has already been utilized but one only needs to refer to such sources as the Census, records of the operations of some of our large corporations, such as loan companies, railway companies, farm implement companies, the Soldier Settlement Board, the Canadian Wheat Board and other agencies, to realize that the surface of a "vein of high-yielding research ore" has only been scratched.

Technological Changes

The second development referred to concerns technological changes of importance to agriculture. To go over these in detail would be the subject of a paper of considerable length. A few examples may serve to indicate the scope of the field. Improvement in the power and design of mechanical vehicles has been marked, new chemicals open the way to greatly increased yields of both plants and animals, and new synthetic products offer both challenges and aids to agriculture. It is indeed unnecessary to go further and remark that these developments have tremendous importance in the economics of land tenure, size of farm, soil conservation, farm labour requirements and a host of other matters. Herein lie fecund fields of research and the challenge is open to the agricultural economist. If he wishes to stay in the vanguard of the sciences he cannot perform a "Rip Van Winkle role" in the face of these facts.

Physical Sciences

It must be recognized that during the war years the physical scientist had a wonderful opportunity to exploit the research field, and he exploited it to the full. Money cost was not an important factor and, under the urgency of war demands, the physical scientist gained a place in public esteem which assures a much more generous support of peacetime research than was the case before the war. But where should their efforts be directed under normal peacetime conditions? For guidance in this we may assume that they will look to the social scientist. Thus, we find another field of opportunity, that of close co-ordination and collaboration with the physical scientist in the development of research programs designed to foster the common weal. Perhaps we, as social scientists, can only go as far as to define the problem—but the suggestion arises that maybe our best efforts will be spent in carrying research through to a practical solution. We may also render great assistance in the general guidance of research into those necessary channels, economics and social sciences.

FUTURE RESEARCH

Consideration of the foregoing implies that future research in agricultural economics will be directed more to the solution of immediate problems and less to fact gathering and description of the problems as an end in itself. The research worker of the future must perforce not only describe the problem but proceed from this to propound a genuine and workable solution.

It has been in this realm so often in the past that the social scientist, as compared with the physical scientist, has been handicapped. With slender resources and, facing the necessity of making a showing, the social scientist has been tempted to publish a bulletin or manuscript, if for no

other reason than to display some tangible evidence of the prodigious labours he has put forth in the task. On the other hand, the physical scientist has not always been burdened by the necessity of producing positive results—in fact, where justified, negative results have in many cases found equal favour. But often he has had the further advantage, that in spite of being confronted by negative results, he has been able to continue his researches until a workable solution of the problem has been found. We must strive to obtain some degree of the freedom enjoyed by the physical scientist for the social scientist in order that the latter may carry his researches to the point of solving problems. This means that the social scientist cannot long continue, as a general program, the descriptive and and fact-gathering techniques, and the terminating of his researches at the point of describing the problem.

Perhaps the solution to this matter in the future will be a much greater degree of integration of research programs in the social and physical sciences. To some extent this has been carried out already, but we can go much further in developments of this kind. In fact, a great deal may be done by "cleaning our own house" of the social sciences by closer co-ordination of research programs.

Discussions with fellow workers in the physical sciences suggest that they would welcome a much greater degree of co-ordination and integration of research projects. Perhaps the agricultural economist will take the lead in this matter and might put forth a greater effort to familiarize himself with developments in the field of the physical sciences. Close association of the agricultural economist within an organization such as the Agricultural Institute is a good omen in this respect.

Lest this paper be interpreted as a criticism of past research in agricultural economics, it would perhaps be well to refer, even if there is some overlapping with Dr. Booth's paper, to past efforts. Do not gather from my previous remarks that all the research done in the past has been lost or is "water under the bridge". A very great deal of it has been extremely valuable to the teacher, the student, the extension worker, the administrator, and the maker of agricultural policy. A good deal of it will be continued with continuing need for such information. In some cases it will be necessary to find and describe the problem before carrying out the further research necessary to its solution. But the developments mentioned heretofore have already brought about, and will bring, a further shift in emphasis from the fact-gathering, descriptive research to research directed to problem solution. This emphasis may come about, without diminishing the existing volume of research, through a large increase in the total volume of which the greater part will be research of the latter type.

In closing, emphasis is placed on the facts that we face a new era, that existing procedures and methods of research are not satisfactory in solving current problems. For the future a dynamic research program in agricultural economics will be required to meet and solve day to day problems. To assist in this task, we should seek improvement in the collection and dissemination of data basic to research programs. It is to be hoped also that ways and means will be found for financing research in agricultural economics on a private basis in order that full opportunity may exist for free and unfettered appraisals of general policy with respect to Canadian agriculture.

AGRICULTURAL POLICY AND AGRICULTURAL ECONOMIC RESEARCH[1]

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This introductory consideration of the above subject will proceed somewhat in the following order. As a first step something will be said regarding agricultural policy as such. Following that, an attempt will be made to show the relationship between agricultural policy and agricultural economic research. Finally, assuming this relationship to exist, it will be necessary to say something about the general objectives of both the agricultural policies and the economic research.

AGRICULTURAL POLICY

In respect to agricultural policy, the first observation that may be made is that it is becoming not only more complex but increasingly economic in character. While there are several reasons for this, the fact is that, as time goes on, governments, willingly or unwillingly, are concerning themselves more with the business, as distinct from the purely technical, aspects of agriculture. Governments are more and more entering business, including the agricultural business. The second point is that it is becoming ever more necessary to regard agricultural policy as part of the general economic policy. This, of course, is bound to be the case as agriculture becomes increasingly commercialized or less self-sufficing in character. What this really signifies is that it is becoming ever more necessary, when formulating "so-called" agricultural policies, to see that they are properly integrated with those pertaining to other sections of the general economy. Another way of putting it is to say that it is getting ever less possible to have a policy designed for the specific benefit of any particular group such as the farmers. Moreover, in view of recent experience, farmers might very well conclude that a general economic policy which results in maintaining full employment is a far better *agricultural* policy than one calculated to achieve some specific agricultural objective such as increasing the efficiency of agricultural production or marketing. In the third place, it should be noted that Canadian agricultural policy is becoming more and more integrated with world policy. In other words, agricultural policy is becoming more international in character. This is particularly true in respect to countries like Canada which have large scale dependence on foreign markets. In view of this dependence it seems obvious that the basic nature of Canadian agricultural policy must be the result of international decisions.

RELATIONSHIP OF ECONOMIC RESEARCH TO AGRICULTURAL POLICY

To the extent that policies have to be economic in character, it would seem that their formation and execution should be accompanied by economic study and research. Common logic suggests that agricultural policies, both general and specific, should be based deliberately on the fullest possible

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

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measure of research. This remains true even though, in a democracy, policies decided upon ordinarily represent not only a compromise between what should and can be aimed at but a cross between the suggestions of pressure groups and those supplied by scientific advisers.

This relation between research and policy making, however, can be considered from at least two standpoints. One may consider the *manner* in which research influence is exerted. In the second place one may consider the *kind* of influence which may or should be exerted by research. In respect to the manner or method, economists and economic research may influence policy either directly or indirectly. That is research may be undertaken with the deliberate objective of evolving a policy or it may merely result in a more scientifically informed public opinion which will, in turn, reflect itself in sounder policies. It is probably true to say that, thus far in this country, the economist's main contribution to agricultural policy in the larger sense has been through research results, dissemination of relevant factual data and a continual education of the general public in economics. In other words, the main contribution has been made indirectly. While this type of influence has been, and will continue to be, both valuable and extensive in the aggregate, it is our feeling that the future will necessitate an increasing amount of research deliberately undertaken in order that policy may be based upon its results.

The question of the kind of influence which research should exert on policy is, however, probably more debatable and also more important than the precise manner in which this influence is exerted. In this connection there are several possibilities. For example, research may be used to determine whether an existing or proposed policy is wise or otherwise. Again, it may be employed to develop programs which will be of assistance in implementing any policy deemed to be desirable. In the third place, research may aid in securing an accurate interpretation of an existing or proposed policy and thereby help to ensure more ready acceptance of it. Such an interpretation would indicate just how far the policy in question might be expected to achieve the objectives sought. Finally, research may well reveal whether, in a given set of circumstances, there is need for any special policy. Perhaps the matter can be stated more clearly by indicating some of the specific purposes for which economic research should be used.

For one thing, we believe that there should be an analytical examination of the actual existing policies and programs in order that an unbiased appraisal of them may be obtained. In the same way, any policies and programmes that are in the serious-proposal stage should be subjected to a thorough, objective examination. Thirdly, on the basis of extensive studies of past experience, the current situation, and actual and proposed policies, constructive research should be directed to the positive task of drafting proposals for policies that seem likely to meet the needs of the situation and to avoid undesirable consequences.

Kinds of Policies

These last statements suggest that any research which is related to policy formation should give a good deal of attention, first, to the determination of policy objectives and second, to the nature of the policies

most likely to attain the objectives selected. In the matter of selecting policy objectives there is room for considerable difference of opinion. One recent writer,[1] for example, suggests that the whole field of agricultural policy should be divided into two main sections. The first would consist of an agricultural production policy which was aimed at making the most effective possible use of available resources. The second section would be designed to further the welfare of farm people and would be concerned with the distribution and use of income among farm people. The same writer adds that, thus far, the United States has not formed its agricultural policy along these two lines and that failure to do so has led to several serious mistakes. He further adds that economists should play a leading part in showing governments and practical policy makers what the flaws in present or past policies are, or were, and what the general nature of future policies should be.

While the two-fold division mentioned above may be reasonably all inclusive, there are probably many who would say that the main objectives of agricultural policy should be:

(a) to protect natural resources against wasteful exploitation and neglect,

(b) to facilitate their effective and economical use for the longer run,

(c) to raise the level of efficiency in agricultural production and marketing,

(d) to promote advances in the standard of living of those engaged in farming,

(e) to increase their security against natural and economic disasters.

There are still others who might insist that the paramount objective should be the fullest possible satisfaction of the nutritional requirements of people everywhere. These suggestions or citations will suffice to indicate how varied the policy objectives may be. They may also suggest a need for some rather fundamental research before objectives are finally decided upon.

When it comes to the kind of policies most likely to reach the objectives, the possibilities are both numerous and varied. We can, for example, divide policies into those which are designed to bear directly upon agriculture, or those engaged in it, and those which, although designed primarily for other purposes, are likely to have significant effects upon agricultural developments. In this latter category may be included immigration and industrial tariff policies; railway and highway construction policies; flood-control, water-power and reforestation policies; currency, taxation and general fiscal policy; and special anti-depression, or full employment, policy. It is also possible to divide policies according to whether they are active or passive, and also according to whether they are emergency or short-run, or continuing or permanent. Moreover, it seems desirable to distinguish between a policy and a program. In this connection, we would suggest that a policy be considered as a course of action, followed (or to be followed) consistently, for a period of years. Programs, on the other hand, might be thought of as the detailed changing measures by which attempts are made to give effect to policies.

[1] See article by T. W. Schultz in May, 1946, issue of *Journal of Farm Economics*.

Types of Economic Research

From what has been said it may be reasonably concluded that economic research, which is designed to assist either directly or indirectly in policy making, must have as its purpose either the *choosing* of objectives or the *achieving* of objectives. It may even be concluded that, if all such research is included, it will be difficult to suggest any type of economic research that is not somehow related to agricultural policies. That is probably true and as it should be. In order, however, that the relationship between research and policy may be indicated in a somewhat more concrete form, we may perhaps conclude this introductory consideration of the whole matter by offering a number of specific research suggestions.

SUGGESTIONS FOR FUTURE RESEARCH

There are a number of policy suggestions that are currently being presented or urged by this or that individual or group. In view of the very considerable measure of support for (as well as opposition to) such suggestions, it would seem highly desirable to have them closely scrutinized by the best available research talent. For example, further careful research is needed to determine the degree of soundness, the possibilities and limitations, of the parity price and parity income concepts. Similar research is needed to decide just how sound it is to aim at providing farmers with a living standard equal to that of some other classes. Similarly special studies are needed to determine the fundamental soundness of such suggested objectives as price and income stabilization, production control, the ever-normal granary plan, crop insurance, agricultural protectionism, international commodity agreements, subsidized food consumption, subsidized production of protective foods so that their consumption may be stimulated, or the wholesale encouragement of agricultural co-operation. Again it would appear to be most desirable and opportune to undertake a study of the impact of widespread acceptance of nutritional science in agriculture. This new approach which, in effect, suggests that the amount and nature of agricultural production should be determined in accordance with nutritional requirements, necessitates and deserves a lot of new thinking.

Speaking more generally, one might say that the economic research needed in connection with current and future policies should include the following:

1. Research designed to bring production more in line with the principle of comparative advantage and the requirements of good nutrition.
2. Research designed to indicate producer and consumer response to price changes.
3. Research designed to indicate the kind of rural welfare policies required.
4. Research aimed at achieving increased efficiency in production and marketing.
5. Research aimed at expanding demand.
6. Research designed to assist in transferring the need or desire for food into an effective demand.

In our view, the problem of maintaining a satisfactory demand for farm products will prove to be the most important and most difficult in the years that lie ahead. While its solution will require much more than agricultural economic research, in the ordinary sense, there can be little doubt that such research must form an integral part of any really satisfactory solution. In this connection, it might be suggested that the relationships between agriculture and the other sections of the economy should receive special consideration in future research undertakings.

Finally, we would suggest that future agricultural economic research projects might be placed in one or other of four general classes. The first class would include all those related to the economics of agricultural production. They would include research in respect of each of the several production factors as well as that having to do with the manner in which these various factors were combined. The second class would include everything relating to the marketing of farm products. There would be some projects designed to secure greater efficiency in the performance of the marketing functions. Others would be primarily concerned with market maintenance or expansion. A third class would include projects relating to farm prices and income. The fourth group might comprise all studies of a socio-economic character. Such studies would investigate the many social and economic implications of modern technological developments. Some of these implications are serious enough to suggest that one of our most serious problems is that of finding a satisfactory social adjustment to technological changes. It is the problem of how to overcome what is sometimes referred to as the cultural lag.

WHITHER RESEARCH IN FARM MANAGEMENT?[1]

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It may help us to orient the shifts in emphasis if we realize that farm management belongs to the inductive sciences, or those sciences that concern themselves with facts. By philosophic definition the inductive sciences are said to consist of four steps in sequence, namely; (1) Observation, (2) Hypothesus, (3) Inference and (4) Verification. The aim of all sciences is to establish laws concerning the activity of the universe, which will assist us in understanding or in controlling our environment.

Those who are familiar with farm management surveys, as conducted in times past, will recognize the surveys and the relationships found, as the first two steps of inductive science, namely observation and hypothesus. The more careful research workers of the past avoided drawing inferences because they felt that they should not do that unless they could also follow up with the fourth step—verification of these inferences. The fact is, of course, that there are very few inferences for which we have developed any checking techniques.

However, this very cautious approach has been subjected to criticism in recent years. The severest critics have pointed out that research only becomes useful when inferences are drawn as the basis for an action program. An illustration of this point would be a survey of dairy farms which indicated a relationship between production per cow and labour income. This hypothesus only becomes usable when we note that the relationship is causal, and that a farmer will move into the higher income group if he can step up his production per cow. Of course, we can leave these inferences to the farmer, and to extension workers, but there are many objections to this policy: chief among these is the fact that they do not know how the study was made and hence are not in a good position to draw correct inferences from it (either as to the strength of the relationship or the conditions under which it would apply).

The resulting reactions among farm management workers to this criticism has varied considerably. In general, the research workers in the United States now agree that conclusions, to be accurate, must be drawn by the research workers. Some of these workers would say that past studies have indicated what the relationships are; that it now remains to draw the inferences in a way that will translate them into a program worked out for individual farm budgets. At first glance, this method might seem to offer a way to put our inferences to the test by following them up with a study to verify them on the original farms used in the survey. However, while there have been budget studies made and published, as yet there has been no attempt to follow them up and see if they were correct or not.

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

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Relationships and Inferences

The more conservative research workers point out that inferences are not likely to be more accurate than the hypothesus from which they are drawn. Our knowledge of relationships in farm management is by no means complete. Take our old friend "size-of-business" as an example; it was one of the earliest factors to be brought out by farm management research. New York, a state that has been largely classified into economic land classes, shows the tendency for a concentration of small farm businesses in the low classes of land, and a concentration of relatively large farm businesses in the best land classes. Thus, grouping by size-of-business also tended to be a grouping by economic land class. Rates of production per cow, or per acre, may be related to types-of-farming and soil-type.

Thus the older census types of farm management surveys served a very useful purpose in focussing attention on the factors affecting farm income, but they did not provide a good basis for studying the strength of those relationships or the variations which occur in different situations. The problem is created by the very large number of variables you introduce when you include every farm in a chosen district in your survey. Something can be done to hold variables within reasonable limits by sorting one factor and then subsorting the factor you wish to study. However, just to list the factors you would like to hold constant will plainly indicate that this method becomes impossible in actual practice. Even if funds and personnel were available to obtain the thousands of records needed, you would have to take in so much territory that it would necessitate introducing additional variables and hence defeat the original purpose of holding variables nearly constant.

Purposive and Stratified Sampling

The more intelligent approach is to define first what you wish to study, and then hold the extraneous variables within narrow limits by definition of the group to be studied. This is really a combination of purposive and stratified sampling. An excellent example of the procedure is to be found in a study of dairy farms in Montgomery County, New York in 1945. There a town was chosen where all the farmers shipped milk to New York city. It covered a one-year period which was the same for all farms. The farms had to be producing wholemilk with all or most of their income from that enterprise and have at least 6 cows milking and be located on No. III or No. IV class land. Thus, the range in location with respect to market, price, type of farming and land class, was held within narrow and known limits and would not be likely to upset, or exaggerate, any reasonably strong trends to be found in the relation of the farm management factors to labour income. There is also a probability in future studies of going further and holding one or more of the farm management factors nearly constant, while variation in the other factors are studied. The survey with stratified sampling to control variables, offers a sound basis for studying relationships, drawing sound inferences and, to some extent, checking those inferences.

It is safe to state that the present trend in farm management research is strongly towards limited objectives with purposive and stratified sampling.

With this goes a tendency towards smaller samples, first because large samples are not so necessary with some of the variability eliminated, and partly because larger samples are likely to introduce more variables.

There is a tendency to obtain purely descriptive data by more extensive methods and wider coverage than labour income studies permit. Since this borders on land utilization, I will not discuss it here, except to point out that determination of the problem, before stratification for relationship studies, may require classification of the farms on a farm unit basis. If for example, you suspected that there was a maladjustment in the type of farming in say Leeds county, Ontario, you would first need to know what the situation there is. This might be learned by using aerial photographs and locating the farm boundaries with the aid of a few local people. With a planimeter you could then determine the total acreage and acreage under cultivation on each farm. The general plan of the farm and approximate intensity of land use could also be determined for each field. Classification of buildings would yield some information concerning types of farming, size of live stock enterprises, and the problems involved if a change of type was found desirable. Such a study is now being organized in New York State as a prelude to a study of relationships. In Virginia land classification is done on a farm-unit basis. This classification would also serve as a basis for stratifying farm samples.

WORK SIMPLIFICATION

While this search for methods that will give us better pictures of relationships is going forward, another line of research is underway. It takes the form of very intensive studies of certain farm management factors with the aid of time and motion studies, or cost accounts, or both together. The most advanced form of this type of study, at present, is the Work Simplification Project, which was organized on a national basis in the United States with headquarters at Purdue University and with the Universities and Experimental Stations of twelve States co-operating.

In the Journal of Farm Economics for February 1946, Lowell S. Hardin and R. M. Carter presented "An Analysis of Work Simplification Research Methods and Results". The authors state that the five main steps involved are to:

1. State the problem and collect input output data for existing methods.
2. Classify and analyse the data.
3. Formulate a hypothesus to show how work methods may be improved.
4. Check and validate the hypothesus.
5. Make available, by approved techniques, any discoveries or developments.

A study of the above steps will indicate that the first four are the four steps of all inductive sciences. In other words, the authors believe that it is possible to carry this type of research right through to the stage of formulating an inference and verifying it.

An example of how this would be accomplished is to be found in a study of chores when caring for poultry in New York State. The problem was stated to be the discovery of the most efficient way to do the chores.

County agents suggested about forty poultry men whom they considered the most efficient in their counties. From these, eight were selected as offering the widest range of techniques to be studied. Research workers, equipped with stop-watches and prepared notation pads, spent enough time at each of these farms to complete records on time and travel over a sufficient period to determine the normal time required in detail. A floor plan of the buildings to scale and with all key distances measured, was prepared in advance to assure accuracy of distances.

The second step was performed in the office, where each of the steps in chores were classified as time and distance travelled in watering, feeding or other jobs. The differences in time required by the different methods used were computed. When this was calculated on an annual basis, the amount of walking to care for 1,000 hens varied from 111 miles on farm No. 1, to 535 miles on farm No. 8; the time varied from 125 to 670 hours. Thus about five times as many hours and miles of walking were required on farm No. 8 as on farm No. 1 to care for 1,000 hens.

The third step was to select the differences in procedure that accounted for the differences in time and movement. Then, the inference could be drawn that other farms could save this time by adopting the most efficient practices. When any of the farms studied change their system, it will be be possible to check the inferences by another time-and-motion study on the new system. The reason it is possible to carry the research through the four steps in this method is that the variables have been reduced to a minimum.

The above example mainly involved labour. If the saving of labour involves an outlay of capital, there would be two interchangeable factors. The only unit of measurement which is common to both is the dollars of cost. In the article mentioned above, it was stated that the procedure would be most useful if linked with cost accounts. Some use has been made of cost accounts in this procedure[1] and more is being considered.

CONCLUSIONS

The intensive study techniques both supplement and implement the studies on causal relationships in farm management. It is not sufficient for a farmer to know that there is a relation between his labour-efficiency and his labour-income. He needs to know, in some detail, what he can do about it! Work simplification provides the best basis both for studying, and demonstrating, the best methods to get high labour efficiency. In the present stage of farm management on the continent there is much to be gained by bringing the least efficient operators up to the level of the most efficient. For this purpose the relationship studies are the only type likely to cover enough situations with the amount of funds and personnel available. We need continuous advance in efficiency if we are to have continuous advance in our living standards. This requires constant advance by the leaders as well as the laggards. Few farms are managed at above average efficiency in all the factors affecting income, and none are as high as they might be. The intensive study of work-simplification offers a more satisfactory way of advancing the techniques of our most successful farmers than does a study of relationships alone.

[1] See "Costs in Harvesting Hay by Different Methods", Agricultural Economics Department, Cornell, mimeograph, Aug., 1945.

WHITHER RESEARCH IN FARM CREDIT?[1]

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DEVELOPMENT OF AGRICULTURAL FINANCE

The problems of farm finance have existed in Canada since the early days of settlement. In its earliest development, agriculture in this country was subservient to the fishing and fur trades, and had to rely on various and diverse agencies to meet its financial requirements. These agencies were all of a private nature such as mercantile companies, British importers, correspondents from London and other centres.

Unlike the developments in the United States, government intervention in farm credit did not appear in Canada until the period of the first World War. Since that time, direct action by government in the provision of credit to agriculture has progressively increased so that to-day we find government directly involved in the long-term-credit field through the Canadian Farm Loan Board and Veterans Land Act, and, in a less direct manner, in the production and short-term-credit field through the introduction of the Farm Improvement Loans Act.

The Canadian agricultural industry today involves large investments. Estimates of farm capital in Canadian agriculture for the year 1943 indicate an investment of $5.28 billion in farm real estate, implements, machinery and livestock. For the same year the gross value of agricultural production amounted to approximately $2.25 billion[3]. To this may be added an estimated value of $1 billion in household equipment, cash on hand, bank deposits, victory bonds, stock in co-operatives and other securities, etc. Thus the total assets of Canadian agriculture for the year 1943 may be estimated to be approximately $8.5 billion. It is likely that this figure is higher now, due to a rise in values and probable larger capital accumulations during the last two years.

On the liability side, the statistics on Canadian farm debt are not as adequate. According to the 1941 census, the total owed by farmers against farm mortgages, agreements for sale and debts covered by liens, amounted to approximately $652 million, of which $629 million involved farm mortgages and agreements for sale.[4] This was a reduction from 1931 of about $42 million in real estate indebtedness. This amount will now be considerably lower, according to all indications respecting farmers' debt repayments.

Non-real estate farm indebtedness no doubt has also reached a low point in the agricultural credit picture resulting from buoyant farm incomes and the inability of operators due to shortages, to replace farm supplies and equipment necessary to maintain the farm plant. Unfortunately, information on this type of credit is not readily available in Canada, if at all.

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

[2] Assistant Professor of Economics, University of Manitoba, Winnipeg, Manitoba.

[3] Canada Year Book, 1945, Dept. of Trade and Commerce, Canada, pp. 200–202.

[4] Eighth Census of Canada, 1941, Dominion Bureau of Statistics, Preliminary report.

This brief review of agricultural finance suggests the importance of credit to the industry. It emphasizes the need for proper credit facilities and the application of methods that will enable a credit system to supply the credit needs of the industry so as to accomplish the objectives aimed at in the industry. At the moment the demand for credit by farmers is not very pressing. It will increase with the increasing number of young men returning to farming, both from the armed services and from employment in war factories or war induced work. Older farmers in their desire to retire, will want to realize on their equities, making credit necessary. Replacement of farm equipment and buildings will also create a demand for farm credit. The trend in this direction is already evidenced in the increasing volume of loans guaranteed under the Farm Improvement Loans Act. To determine what constitutes an adequate credit system, research in farm finance can make an important contribution.

A program of research in farm finance could not be complete without prior appraisal of research in the field. This involves a review of research completed, a knowledge of research in progress and some familiarity with contemplated projects. The writer only had a limited time in which to investigate this phase of the work. However, the investigation that was possible did not reveal any developments in the latter two aspects of research directly concerned with farm credit. There are some studies in progress on problems of farm management, land appraisal and land use which relate to farm credit, but in respect to projects of direct concern to credit, none could be discovered. This is due, perhaps, to the scarcity of trained personnel, the lack of funds and to the extraordinary demand during the war on the time of those who could have carried on such studies.

It was possible to review in varying degree of detail about 60 publications dealing directly with farm credit in Canada. As far as could be determined, this covered about the entire portfolio of material available on the subject. The material reviewed divided itself into the following categories:

1. Acts of Legislatures and Parliament, explanatory reports and articles with respect to the operation of these Acts; reports by credit agencies indicating their loaning position and some statistical material.

2. Commission and Committee reports investigating the need for farm credit, study of facilities in other countries, and recommendations for the establishment of credit agencies in Canada;

3. Historical presentations and analyses of farm credit in Canada, dealing mainly with the development of the credit facilities and factors influencing that development;

4. Loan experience studies within areas and regions treating the problem from the point of view of capacity to repay and the nature of the loan terms.

This brief review of the material dealing with farm credit suggests two situations. First, that the amount of research done in Canada in farm credit is small and therefore the field is clear for a complete, well integrated

program of research. In the second place, the proportion of publications of an analytical nature is small compared to the number published as direct records of credit laws, explanations of the laws and of credit agency activities. The ratio is about 1 to 4. In other words, even assuming that the material reviewed does not represent the complete list of published information on the subject, it is representative enough to indicate the trend in the nature of the work. This observation is not designed as a criticism, but rather as a warning, so that when a program of research is outlined, the emphasis should not be placed on one aspect of the problem. That this can happen is evidenced by criticisms of research programs in the various fields of agricultural economics in the United States.[3]

OBJECTIVES

A first approach to the study of farm credit must give consideration to the objectives to be attained. The prime objective of credit to agriculture in the past, particularly of farm mortgage credit, was to facilitate farm ownership. The question that arises now is whether this objective has been attained. Farm ownership and operation are becoming progressively further separated in the cultivation of the land. Technological developments that tend to increase the size of farm, permit a lesser number of operators to cultivate larger acreages, but the capital required to own that entire acreage is generally beyond the capacity of many individuals to accumulate. It is suggested that ownership of all the land by its operators may tend to hinder those climbing the agricultural ladder, and prove a handicap to those seeking an efficient size of farm. Therefore, it can be argued, the purpose of farm credit may be considered from other points of view as well as that of farm ownership.

Our agriculture developed in a competitive economy. Under such an order, farm credit was a matter of concern only between the lender and borrower. Each loan, if it was a good one, was designed to economize the resources of each party to the loan. It presumed the most efficient use of resources; and each loan was expected to be self liquidating. Today, however, we are departing from this position. Government intervention in the credit field, either through easier credit or through debt adjustment, enables less capable operators to work land without full regard for maximum utilization of resources.

The tendency for government to participate in farm credit is an extension of government policy in directing the industry. Governments are actively involved in agricultural marketing, production controls, prices, land use, settlement and credit. Such action is decreasing the freedom in agricultural enterprise previously experienced. This greater government control of the industry, the tendency away from ownership, and the probable lesser importance of ownership as compared with income in agriculture must have an important bearing on the objectives of farm credit.

[3] See: F. L. Thomsen "A Critical Examination of Marketing Research." Jour. of Farm Economics, Vol. XXVII, Nov. 1945.
F. F. Hill, "Research Developments in Farm Finance." Jour. of Farm Economics, Vol. XXVIII, Feb. 1946.

Definitions

A study of the objectives of farm credit naturally leads to a definition of credit. As commonly considered credit involves financing in a manner whereby the enterprise will provide a return to pay all the costs of the loan, increase returns to the operator and enable repayment of the original amount. This may be considered as business credit. Within recent years, however, we have experienced a departure from this form of credit in agriculture. We have developed an easy credit, with a welfare aspect, designed to assist certain elements in the industry because to do so is in the best interests of the nation. Welfare credit, if it may be so designated, is a recent development in Canada, having been resorted to mainly since the depression of the thirties. Such credit disregards previously considered safe margins of equity by the borrower, provides for uniform and low interest rates, irrespective of costs and risk, and, in the case of the Farm Security Act in Saskatchewan, provides for cancellation of debt under certain conditions.

In line with the need for definition of credit, there is the need for definition of a farm. The 1941 census defines a farm as all the land of one acre or more, operated by one person with his own labour or with the assistance of his family, or with hired help, which produced in 1940 agricultural products to the value of $50 or more. It is readily seen that such a definition does not distinguish sufficiently between the various types of farms.

The credit needs of commercial farms are vastly different from those in the subsistence category. Size and type of farm are important in the determination of the kind of credit required and the terms and methods of administration. Within each group is to be found a high-risk area where any sort of loan cannot be of permanent benefit to the individual.

The wide variations in the farming methods used, in the farm incomes, and in all the other characteristics of farms and farming in Canada must be recognized in the formulation of any agricultural policy such as farm credit. Without proper definition and differentiation of farms, we get a false assumption of uniformity in the industry which is bound to influence our thinking on problems of agriculture.

Special forms of credit for agriculture have always been defended on the basis of the peculiar characteristics of the industry. Agriculture is not a homogeneous industry. It is made up of numerous small, individual and diverse units existing even within the same general type of farming, and within a single geographic area. It is affected by the length of production period, by fluctuating prices and output over time. Transfer of ownership at least every generation adds further to the problems in financing agriculture. The risks caused by these peculiarities of agriculture have been responsible for a higher cost of credit to the industry and have necessitated a different set of credit facilities to serve its needs. Agricultural credit has been divided into long-term, intermediate, and short-term and lenders have generally used this classification, as the basis of extending credit to farmers, rather than to attempt to adapt the credit provisions to meet the differences that exist among individual farms as caused by local circumstances, and changing technological and economic conditions in agriculture.

A re-examination of agriculture in relation to its financial needs would appear due now. There undoubtedly is an accumulation of changes in the industry caused by the war, population movements, government action in respect of prices and production, as well as from technological improvements, notably the greater extent of mechanization. We should attempt to obtain the information concerning these changes and to determine if there is any clearer definition possible among individual farms and regions in their use of credit. We require information with respect to the use of capital by farmers, and the outside limitations in equity requirements for different farms and areas.

A question that should be investigated and studied is how corporate-type of finance may be applied to agriculture. Land is a non-depreciating asset, and therefore affords satisfactory security for any loan. How can our credit be organized to permit farmers to operate on continuously borrowed capital paying the interest only? The answer to this question may also provide a clue on how to avoid the expense and physical disturbance occasioned through the transfer of ownership of a farm at least once every generation.

Research in the characteristics of agriculture in relation to its financial needs will provide answers not only to the above but also to questions of capital use, capital accumulation and depletion on the farm according to type and region.

Credit Terms

Over the years, progress has been made in Canada in the matter of credit terms. In the case of real estate mortgages, the amortization principle has been adopted, the repayment term has been extended to 20 or 30 years, and provisions for complete repayment at any instalment date are included in almost every farm credit contract. More flexible provisions are also provided in the shorter term credit field, notably those guaranteed under the Farm Improvement Loans Act. Further adjustments in the terms of agricultural loans, however, are needed to fit the peculiar requirements of agriculture. Agricultural income has a high degree of variability which is reflected to the individual farmer in a fluctuating capacity to pay debts. A rigid amortization plan does not consider such fluctuations. A repayment plan providing for larger payments during high income years, to offset inability to meet the instalment in poor income years, seems a desirable feature in farm mortgage credit. Dr. Hudson pointed to this fact very clearly in his study of loaning experience in Saskatchewan.[4] A variable repayment plan, that will make it mandatory for larger payments in high income years, within certain limits of debt, would seem desirable. At least, it would appear that a definite statement, included in the loan contract, as to amounts and conditions of a variable repayment plan, even on a voluntary basis, may serve a very good purpose. It is admitted that lenders prefer a definite repayment plan and borrowers prefer a variable plan, in poor years more so than in good years. If such a plan will aid in providing more satisfactory credit, and a more suitable repayment program, it is one that should be recommended and adopted.

[4] Factors Affecting the Success of Farm Mortgage Loans in Western Canada. S. C. Hudson, Dominion Dept. of Agriculture Tech. Bul. No. 41. April 1942.

Mention has previously been made of the uniformity in loan terms as contrasted with the method of fitting loan terms to the varied needs of individual cases. This is especially significant in the matter of interest charges, loan fees, and differentiation of risk, among the various farms and regions. There are limitations mainly of an administrative nature in defining terms on such a basis, but it is a matter of sufficient importance to warrant a possible solution. Considerable progress could be made in fitting loan terms to different farming conditions, and for various regions, by studying costs of loaning, risks involved, pure interest on an alternative opportunity basis and repayment plans. In this regard, attention should be given to the possibility of loan insurance or guarantee as a possible means of safeguarding the lender's investment. The National Housing Act, and the Farm Improvement Loans Act, are based on this principle. Research should be directed towards determining its use in all agricultural loans. It may provide an answer to the financing difficulties in extra-risk lending.

Private Credit

Since 1930, private lending institutions have almost completely withdrawn from the farm credit field in Canada. Neither real estate nor production credit was available to farmers from private sources; this resulted in a more complete entry into this field by government. With the exception of the credit provided by the Canadian Farm Loan Board, government loans were provided on an emergency basis. Until the passage of the Farm Improvement Loans Act shorter term credit was spasmodic and unorganized in terms of a system. The periodic withdrawal of private agricultural lending agencies during depression periods places an extra burden on government and emphasizes the deficiencies in our credit system with respect to agriculture. It stresses the need for information on the position of the various credit agencies, and the extent of participation expected from each. Some agreement should be reached as to the role of government in agricultural financing. Should it be a pace setter, should it assume a significant position in supplying the needed volume of credit, or should governments only appear in emergencies to "bail out" private lenders.

Government Credit

A casual examination of government agricultural credit policy in Canada would lead one to the conclusion that it is designed to leave this field primarily to the private agencies, seemingly a proper decision in an individualistic economy. This policy places definite responsibilities on private agencies among which continuous provision of credit is of major importance. It does not appear correct that private institutions should appear as competitors, under favourable conditions (to them) of lending and withdraw, when conditions are not so favourable or when alternative opportunities are more favourable. If credit is to benefit agriculture it must be ample and continuous. Ability to repay, and not security alone, must be recognized as the criterion for lending. In the past, private lending agencies have extended credit to farmers during periods of inflated prices and values, considerable repayment being made under conditions of deflation. Such repayment has been made possible, to a degree, through farmers refinancing

with government agencies. This places an extra burden on government and the taxpayer through necessitating subsidized credit. To clarify the respective roles of the various credit agencies, research is necessary.

Co-operative Credit

Any consideration of lending agencies, and their suitability and adaptability to agriculture, must focus attention upon the place of co-operative credit agencies. The use of co-operative credit in agriculture, especially as exemplified by credit unions, leads to the conclusion that such agencies may provide credit on a satisfactory basis. One very attractive feature of this type of credit agency is its closeness to the borrowers. Being credit "on the spot" co-operative agencies can adjust the type and terms of their loans to better suit local conditions. Furthermore, such credit is primarily based on need and ability to repay.

Providing proper rediscounting privileges are available to co-operative credit agencies, it would seem that such agencies can enter every field of farm credit on a continuous basis. The experience of the Farm Credit Administration indicates the practicability of co-operative credit in both the long term and shorter term fields. The defects in that system which converted it from a purely co-operative agency to a semi-governmental agency may be traced in part to the limitations and restrictions placed upon it, regardless of circumstances, by exponents of cheap and easy credit

A full appraisal of co-operative credit is necessary to answer questions with respect to the following:

1. Cost of loans to the agency and to the borrower;
2. Use to which the credit is put and its effect on the borrowers' business;
3. Possibility of using the budget plan in lending, that is, extend the credit as it is required;
4. Repayment methods and their effect upon the farm business;
5. Effect of co-operative credit agencies upon the morale of the agricultural community as well as its welfare aspects.

CONCLUSION

The observations presented above are neither intended to be exhaustive of the topic, nor definitive. The objective was to point up some of the features of a desirable approach to research in the direct field of agricultural credit. Other aspects of the problem will suggest themselves as the various features discussed here are investigated.

While the discussion, as presented, attempted to restrict itself to credit only, it is not suggested that a program of research should completely segregate the study of credit from that of related fields. Considerable research has been conducted, and studies published, in farm management. In practically every one of these studies, the question of farm capital is considered. Farm management studies, however, have not dealt sufficiently with the question of capital use, accumulation and depletion. All studies observed by the writer, and there is a strong sameness among them, are mainly descriptive, and because of the use of the "average" in analysis, are

too general to provide definite conclusions with respect to credit. Perhaps that is the objective of farm management research. This fact, however, does not preclude the possibility of utilizing data obtained in these studies for further analysis with respect to farm credit. A similar observation may be made with regard to the land use studies in progress and completed. The point at issue is, that while research in farm credit requires the segregation of the several individual aspects of the problem, all these separate elements should be integrated into a whole, and co-ordinated with research work and conclusions in related fields.

It is not suggested that the determination and establishment of an adequate and suitable farm credit system will completely solve the agricultural finance problems. Prices of farm products, the degree of variability in income, the fluctuations in land values due to the rapid capitalization of fluctuating farm incomes, and many other factors, all have an important bearing on the operation of an efficient farm credit system as an aid in attaining the objectives of a progressive agricultural industry. But dealing with farm credit itself, Canadian lenders and borrowers require information of the kind suggested above. We require more complete statistics on farm credit, we need more descriptive research dealing with loan experience, and we require studies using the problem-approach to suggest probable future trends and developments in farm credit. This can be accomplished through a well integrated program of research in which government, private institutions and universities can well co-operate.

WHITHER RESEARCH IN LAND ECONOMICS?[1]

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In order to delimit the scope of this discussion I wish to preface my remarks on research in land economics with a definition of the term. Land economics is defined by Ely and Wehrwein as "a science which deals with the utilization of the earth's surface, or space, as conditioned by property and other institutions and which includes the use of natural forces and productive powers above or below that space over which the owner has property rights" (5). Stated more simply, land economics deals with the utilization of land by man. The use of land must conform to natural laws. It is also influenced by customs, traditions, laws and institutions. In a commercial society, land use is conditioned by costs and income and will be determined largely by the maximum net profit. Land economists, therefore, must consider the physical, the institutional and the economic points of view. In attempting to indicate the direction which research work in land economics in Canada should take, it would seem desirable to examine some of the work which has already been done within the various branches of land economics.

LAND UTILIZATION

The most widely developed category of land economic research is land utilization. "In the applied phases, land utilization analysis consists of the study of the land resources of an area with a view to determining for what, and how, they may be most economically employed: in its pure science phases, it involves an attempt to explain existing uses of land and to develop a body of principles relating thereto" (3). The most common study in this class involves a description and extension of the land use of an area. Such studies provide a fundamental basis for work in farm management, land settlement, agricultural policy and other phases of agricultural economics (8). Land utilization is so closely associated with farm management that it is often difficult to note the demarkation of the two fields of work. While in farm management analysis, the point of view is usually that of the individual operator, in land utilization the social or collective point of view is of more importance. An important type of study which, while closely associated with farm management is more properly classified under land utilization, is types-of-farming. A new study of types of farming in Canada, which will be a revision and an extension of an earlier study by McArthur and Coke published in 1939, is at present under way (9). It is felt that such a study provides worthwhile information, not only in the field of agricultural education, but also as a background to the application of agricultural policies.

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

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Land Classification

A type of land utilization study, and one which has been in great demand as a general guide to the planning of land use, is that of land classification. The objectives of land classification are dealt with in some detail by Barnes (2). The general problem of classification, as expressed by Kellogg and Ableiter is, "To place objects classified into suitable categories, the better to study and remember their characters and to show their relationships" (10). There are two aspects of the problem of land classification, the physical and the economic. The former takes into consideration climate, soil, topography and crop adaptation, while the latter considers the highest economic use of land resources. Land classification has received much attention in Western Canada since the drouth period of the 1930's. In this area six studies of land classification have already been published by the Economics Division, Dominion Department of Agriculture and others are in the course of preparation. While three studies in land use classification have been carried on in Eastern Canada in recent years, it is imperative that more attention be given to this work in all provinces. Various measures of long-term economic returns have been used in land classification work. These indexes include building classification, tax delinquency, indebtedness and farm abandonment. Long term yield data has been used as the principal criterion in Western Canada. The technique developed in land classification work in this area is well described by Stewart and Porter in their publication on Land Use Classification in the Special Areas of Alberta (11). An effort is being made to develop research techniques in land classification adapted to the northern areas of the Prairie provinces. Recent experience by the writer in connection with a preliminary study of land use in Prince Edward Island suggests a new measure, an index of intensity as measured by labour in-put or number of man-work-units per acre occupied. This measure is based on the thesis that the degree of intensity by which the land resources of an area are exploited is the result of the long-term experience of individual farmers, and as such reflects economic returns. Results to date indicate a high correlation between this measure and soil type, valuation of land per acre and sales of farm products per acre.

While practice has dictated that consideration of the physical attributes of land must precede the consideration of its economic usefulness, it is suggested that land classification is a function on which the soil scientist and the economist can work to advantage as a team. Under such a plan the collection of economic data might be carried on in conjunction with the field work in connection with the soil survey. Such a scheme would provide for continuous consultation between the soil scientist and the economist.

Land Tenure

Another important category in land economics is land tenure. Most studies in land tenure in Canada have been historical and descriptive in nature. In one or two instances, attention has been given to a basis for the establishment of rental contracts (13). In spite of public policy which historically has fostered freehold tenure, leasehold has been increasing in

importance in most provinces in Canada (4). In view of this trend, greater consideration should be given to the necessity of carrying on research work which will provide a basis for legislation to ensure greater security of tenure to the tenant and to provide payment to the tenant for capital improvements made and to the landlord for depletion of the soil and for damages to permanent farm fixtures. Consideration should also be given to the type of tenure best adapted under varying conditions in different parts of Canada. The desirability of public ownership of certain lands in the southern part of the prairie provinces has been indicated as a result of the crop history of this area.

Land Valuation

Another category in land economics which has received little formal attention from the research worker is land valuation. While some contributions in this field have been made as a by-product to certain studies in land classification and farm finance it has, for the most part, been neglected. Present inflationary tendencies in land values, as the result of an increase in the prices of farm products, have created an urgent need for research work in land valuation. If some of the disastrous consequences of the 1920's are to be avoided in the future, this type of research is essential. Land appraisal is a science and can only be carried out satisfactorily if the appraisor is provided with the necessary tools by the economist.

Land Taxation

Studies carried on in rural taxation have indicated great inequalities in the distribution of taxes levied on land. Research in this field should be directed towards a more efficient system of assessment and a re-distribution and a reduction of many of the costs of local Government which are borne by the farmer.

Land Settlement

Early studies in the field of land settlement in Canada were largely from the historical approach. A number of worthwhile contributions to research in land settlement in the newer areas of Canada have been made in recent years by Gosselin, Boucher, Acton, Stutt, Van Vliet and Spence (1, 6, 7, 12, 14). Further extension of studies of this type together with an examination of land settlement methods used in various European Countries, notably Holland, is essential as a basis of future land settlement policy.

There is also great need for research in connection with property rights, contracts, registry, description and transfer of lands in Canada. Study of land prices and transfers over a period of years would provide a basis for extending and improving present statistics.

While an attempt has been made to indicate the direction which research in land economics might take, it has not been possible to deal with the subject exhaustively in the time allotted.

Much creditable work has already been accomplished in this field. It is to be hoped that the future will see an even greater effort being exerted to provide a fund of essential information on our land resources in Canada, which may finally culminate in an intelligent long-term land utilization policy.

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WHITHER RESEARCH IN AGRICULTURAL PRICES?[1]

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DEVELOPMENT OF AGRICULTURAL PRICE POLICY

During the past twenty-five years price analysis has become an increasingly important sub-field of research in agricultural economics. The resultant class of agricultural economists known as price specialists, have concentrated on the study and interpretation of prices—in this instance more particularly the prices of farm products. Their field of research takes in all aspects of the price making process.

Research in farm prices cannot, of course, be confined to a compartment hermetically-sealed off from the other divisions of agricultural economics, any more than should the study of agricultural prices be entirely separated from price studies for other products. Price analysis naturally spills over into other sub-fields of agricultural economics, notably marketing, farm management and agricultural policy. As a matter of fact any detailed study of the production, consumption or marketing of farm products ultimately involves some phase of price research. For this reason, most of the projects in which price specialists engage also concern and involve collaboration with marketing economists, production economists and farm management specialists, and vice versa.

The important socio-economic changes during the last quarter century, punctuated by a major industrial depression sandwiched in between two world wars, could not fail to have profoundly affected the trend of agricultural price research. Economic organization has tended to drift away from "laissez-faire" towards a system in which a varying degree of economic control is more or less accepted. This process appears to have been greatly accelerated during World War II. At the same time, price research has rapidly passed through its adolescent stage of purely descriptive studies, followed by attempts to explain, and analyse, price behaviour. Before price analysis has reached a mature stage and before the depression-born pastime of price prediction and forecasting had reached anything like perfection, we found ourselves engaged in price control—an experience analogous to taking over a puppet show without much practice with the strings.

As a result of these developments, there has been a decided shift of emphasis in the agricultural price field. During the hey-day of farm management research, it was more or less assumed that price movements were pretty much out of the control of the individual farmer, and thus he should adjust his plans for the organization of his farm business in conformity with current price trends. In the depths of the depression, however, farmers found such procedure limited for there were virtually no profitable lines of agricultural production to which they might shift. This inevitably paved the way for demands by producers for public price support

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[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

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programs. Agricultural prices were just beginning to emerge from the depression doldrums when World War II arrived. This brought about an abnormal demand for farm products but, before this situation had exercised maximum effect on farm prices, we entered the public price control period from which we have not yet emerged.

The present period of transition from price control to price stabilization seems then to be an opportune time for a brief look in retrospect as to where we have been going in the field of price research. Then we will be in a better position to face the question of the moment– Where do we go from here? It would be difficult to suggest in what direction agricultural price research should proceed, without making some assumptions respecting the probable trend of agricultural policy during the next few years. Can we assume, for example, that the legislation which created the Agricultural Prices Support Board in 1944 is indicative of a period in which stabilization of farm prices and income will be a fundamental objective of government agricultural policy? Can we also assume that centralized marketing boards, marketing schemes and other price stabilizing marketing agencies will continue to be widely supported?

If we accept these developments as likely to persist in the immediate future, research in agricultural prices should recognize this fact: price theorizing, based on purely competitive demand and supply relationships, will not be realistic if prices for farm products are not provided with some of the stability exhibited in the past by other non-farm commodities. If we are to have forward pricing arrangements for farm products, there will be less need for concentrating efforts on price forecasting, or on the familiar historical studies of seasonal, cyclical or long term price trends. Whatever research is attempted should rather be designed to assist the work of public price-administering boards.

If we are likely to experience a period characterized by a certain degree of price control and support for farm products, farmers will not be so concerned with making individual production adjustments to changing prices, as they will be in pressing their demands, through national and even international farm organizations, for adequate prices for, and efficient distribution of, their products.

Agricultural Price Research

In view of these trends so briefly outlined, what lines of agricultural price research seem most opportune?

Types of research studies in the farm price field, which have been or could be undertaken, exhibit wide variety. Among the more important might be set down the following projects: those

(1) involving the collection and compilation of basic data;
(2) involving studies of the general nature and behaviour of agricultural prices;
(3) in price forecasting;
(4) relating to price spreads and marketing margins;
(5) involving problems of price control and support policy.

In a paper of this length, it is obviously impossible to enter into a detailed discussion of all of the various types of farm price research projects which might prove useful in the near future.[1] I will therefore confine the balance of my remarks mainly to projects which might assist in the intelligent administration of price control and stabilization policies.

In passing, however, I think it pretty well goes without saying that virtually no type of price investigation can proceed without basic data. There have been in the past many inadequacies here. Reliable price series for Canadian farm products are still too meagre, especially with respect to prices received at the farm. Price data for central, wholesale markets are reasonably satisfactory, but at most other stages in the marketing process from farmer to consumer, adequate price series are not readily available. In some cases, series which do exist vary in more than one of the three variable factors of time, place and form[2].

To remedy these shortcomings, two possible approaches suggest themselves:

(1) Consideration should be given to the need for reporting and publication of more complete price data at various market points.

(2) Existing sources of historical price information should be more fully explored, e.g., local newspaper files, records of local mills, elevators, creameries, stores, co-operative associations and farm account books.

In addition to providing more adequate basic data for the price investigator, there would be made available price information required in the examination of margins at various stages in the marketing process. We do not have in Canada as yet any up-to-date and comprehensive information available on price spreads from farmer to consumer, such as that compiled by the Bureau of Agricultural Economics in Washington. This might be a useful combined project for Canadian price and marketing specialists to embark on at an early date.

Agricultural Prices Support Act

Since we have already gone a long way in the direction of public price control and support programs for farm products, it seems logical to assume that a fundamental criterion in the selection of projects in price analysis, to be undertaken in the immediate future, should be their possible application in the administration of agricultural price policy. As a case in point, under the 1944 Agricultural Prices Support Act, we now have a Board empowered to prescribe prices for agricultural products in Canada and, to either purchase commodities at these prices, or pay producers any deficiency between the market price and the prescribed price. I do not know how the Agricultural Prices Support Board proposes to determine its "prescribed" prices, but surely it would welcome any assistance in the field of price research which would help to answer such practical problems as these:

[1] For a more detailed discussion of price research projects see "Research in Prices of Farm Products" edited by John D. Black, Bulletin No. 9 of Social Science Research Council, N.Y. (1933).

[2] For further discussion on the variable factors in price research problems see Shepherd, Geoffrey S.—"Agricultural Price Analysis" p. 38–39. Iowa State College Press (1941).

effects on supply of various levels of prices for each commodity; what seasonal or regional variation in prices or grade differentials are desirable; what level of domestic consumption may be expected at various prices.

Another phase of the Agricultural Prices Support Board's responsibility has to do with securing "a fair relationship between the returns from agriculture and those from other occupations". This of course introduces the oft-quoted but too often misunderstood, "parity price" idea. Here is an opportunity for the price specialist to shed more light on what is involved in the concepts of parity prices and parity income, and to devise better ways and means of measuring and expressing the relative level of agricultural prices, as it affects the general economic position of the farmer.

Public Price Control Agencies

There are also in the provincial field a number of public bodies concerned in the marketing and pricing of farm products. In this category, are included Milk Control Boards and Commodity Marketing Boards established under Provincial marketing control legislation. Although in some cases these organizations operate primarily on a price negotiating or bargaining basis, most are in a position to benefit from the work of the price specialist. In Ontario, for example, there are marketing schemes operating for a number of commodities under the 1937 Farm Products Control Act. The most recent and far-reaching of these covers the marketing of hogs. Under this legislation, a Local Board is empowered to negotiate a minimum price for hogs several months in advance. To do this intelligently involves a forecast of the demand and supply situation, and a pretty thorough analysis of all price determining factors. Otherwise, the price negotiations will merely consist of a higgling and bargaining process between producer and processor representatives.

These public price control agencies must employ a rational approach, in arriving at appropriate forward prices for the various farm commodities with which they are concerned, rather than base their decisions mainly on political expediency, the relative bargaining power of pressure groups, or even on cost of production calculations. If this is found possible, then various types of agricultural price analysis should be of material assistance. Of particular value would be studies of producer and consumer responses to price changes involving analyses of the elasticity of demand and supply for various commodities. There should also be special study of the problems likely to arise from interference with the normal function of prices in regulating the production and consumption of agricultural products. Since price is the factor over which it is desired to exercise a degree of control, it will not be necessary for price specialists to perfect better techniques for price forecasting, but rather to concentrate on forecasting the demand and supply conditions likely to prevail in the appropriate future period. Thus, by appraising these factors and their probable interaction, price specialists should be prepared to suggest what approximate price will be likely to bring forth a supply in line with requirements. This type of analysis, while applicable to domestically consumed products, naturally becomes more and more complicated as we move into the international field.

One point which seems worthy of special mention, is that if we are entering a period of regulated, or if you like, stabilized prices, for farm products, we will at the same time be leaving farther and farther behind the so-called "normal" or pre-control period. Thus, we will have no recent experience under purely competitive price making from which to draw. On the other hand, it will be possible for the price specialist to observe at first hand the effects of various types of price controls, and there will be a ready proving ground on which to test out his theories of how the price-making mechanism operates.

These brief remarks are only intended to pave the way for further discussion on the topic—Whither Research in Agricultural Prices ? I hope, however, that I have been able to register my firm conviction that future research projects in agricultural economics in general, and price analysis in particular, should avoid falling into the category of "arm chair theorizing", and should be applicable in a practical sense to the current problems of the public administrator.

WHITHER RESEARCH ON FARM INCOME?[1]

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NET NATIONAL INCOME

Estimates of Net National Income at Factor Cost, recently published by the Dominion Bureau of Statistics, are compiled on a factor share basis with the exception of the net income of unincorporated individual enterprise. A separate classification of the income of unincorporated individual enterprise is required because it includes a mixture of salaries, wages and investment income which could only be obtained separately on a very arbitrary basis. Table I, taken from Page 6 of National Accounts Income and Expenditure, 1938-1945, shows Net National Income at Factor Cost and Gross National Product at Market Prices and gives, under Item 4, the net income of individual enterprise. A substantial part of the income of individual enterprise is composed of income accruing to farm operators from current farm production. It is to be noted that figures of net income of farm operators from current farm production do not measure the total income of farmers. To arrive at their total income, it would be necessary to add the following items, given on the right hand side of Table II:

(1) net rent on owner-occupied farm houses
(2) net transfers under The Prairie Farm Assistance Act
(3) payments made under The Prairie Farm Income Act
(4) net rent of rented property
(5) interest and dividends
(6) income from other activities such as fishing, trapping, lumbering road work, etc.

TABLE 1.—NET NATIONAL INCOME AT FACTOR COST, AND GROSS NATIONAL PRODUCT AT MARKET PRICES, CANADA, 1938, 1941 AND 1945
(million dollars)

Item No.		1938	1941	1945 Preliminary
1.	Salaries, wages and supplementary labour income	2,449	3,529	5,037
2.	Military pay and allowances	9	386	1,089
3.	Investment income	692	1,518	1,811
4.	Net Income of individual enterprise, agricultural and other	790	1,081	1,690
5.	NET NATIONAL INCOME AT FACTOR COST (1) + (2) + (3) + (4)	3,940	6,514	9,627
6.	Indirect taxes less subsidies	646	1,062	992
7.	Depreciation allowances and similar business costs	504	684	750
8.	Residual error of estimate*	−15	+75	−10
9.	GROSS NATIONAL PRODUCT AT MARKET PRICES (5) + (6) + (7) + (8)	5,075	8,335	11,359

SOURCE: National Accounts, Income and Expenditure, 1938–1945.
* Balancing item for reconciliation with Gross National Expenditure at Market prices.

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.
[2] Statistician, Agricultural Division, Dominion Bureau of Statistics, Ottawa, Canada.

Of these six items, information on income receipts by farm operators is available only for the first three. These three are included in estimates of net income of farm operators from farming operations published by the Agricultural Branch of the Bureau of Statistics.

The left hand part of Table II shows net income of farm operators from farming operations and the components from which it is derived. Included are: estimates of cash income from the sale of farm products, values of income in kind, values of changes in inventory of farm stocks and the supplementary payments made under PFA, PFI and WAR. Farm operating expenses and depreciation charges are subtracted from the total to give net income of farm operators from farming operations.

In order to arrive at estimates of the total net income received by farm operators, it is necessary that we obtain the additional amounts which they receive under items (4), (5) and (6) listed above. Net income so computed could then be defined as the total amount which farm families have for living expenses, for the payment of income tax, and for investment in the farm enterprise or some other investment outlet.

The amounts received under Items (4), (5) and (6) are included in the national income under the appropriate headings. At the present time, however, there is no information available which will enable us to determine separately the amounts which farmers receive under these three headings. It is hoped that the census of the Prairie Provinces, taken this summer, will obtain data on which such a separation can be based. For example, the schedule is so arranged that the proportion of the total rent paid by farmers which is actually received by other farmers may be determined. The interest on mortgage indebtedness is handled in a similar manner. As well, we hope to obtain an indication of the net income farmers receive from such non-farm enterprises as fishing, trapping, road work, outside labour, etc. Similar information is needed for the remaining provinces, and could be collected by the decennial census. Still required, however, will be information as to the amount of interest farmers receive on bonds, bank balances and non-farm mortgages as well as rent on non-farm property. As it is not feasible to obtain such information through the census, a special survey may be required.

FARM INCOME

In addition to obtaining information on the above noted sources of income, there are other sources, supposedly included in farm income, about which we require additional information and regarding which our concepts must be more clearly defined. The difficulties arise, oddly enough, in determining income from farm products themselves.

Income accounting for the farm group is considerably more complicated than it is for the individual farm. In the case of the group, care must be exercised to remove duplication. That is, interfarm sales must be eliminated, or they must at least appear on both the income and expenditure side, in order that the net income will include no duplication. On the one hand, this involves determining what final sales are, regardless of whether these final sales be to farmers or to other industrial groups. On the other hand, it involves the determining of the value of goods and services used in

TABLE 2.—INCOME OF CANADIAN FARM OPERATORS, 1938, 1941 AND 1945

(thousand dollars)

1938	1941	1945 Preliminary	
664,317	914,039	1,654,165	Cash Income from Sale of Farm Products
188,791	200,790	263,480	Income in Kind
+35,811	−38,884	−185,400	Value of Changes in Inventory
888,919	1,075,945	1,732,245	Gross Income
465,062	517,976	683,830	Operating Expenses and Depreciation Charges
423,857	557,969	1,048,415	Net Income Excluding Supplementary Payments
—	69,443	13,000	Supplementary Payments[1]
423,857	627,412	1,061,415	NET INCOME OF FARM OPERATORS FROM FARMING OPERATIONS

	1938	1941	1945 Preliminary
NET INCOME OF FARM OPERATORS FROM CURRENT FARM PRODUCTION	408,100	578,249	1,034,915
(a) Plus Net Rent on Owner Occupied Houses	15,757	16,587	18,000
(b) Plus Net Transfer under Prairie Farm Assistance Act	—	13,593	9,400
(c) Plus Payments under Prairie Farm Income Act	—	18,983	—
NET INCOME OF FARM OPERATORS FROM FARMING OPERATIONS	423,857	627,412	1,061,415

(d) Plus Net Rent on Farm and Non-farm Property
(e) Plus Interest and Dividends
(f) Plus Net Income from fishing, trapping, lumbering, road work, etc.

EQUALS TOTAL NET INCOME RECEIVED BY FARM OPERATORS

(d) Plus Net Rent on Farm and Non-Farm Property
(e) Plus Interest and Dividends
(f) Plus Net Income from fishing, trapping, lumbering, roadwork, etc.

EQUALS TOTAL NET INCOME RECEIVED BY FARM OPERATORS.

[1] Payments received by program of the year under The Prairie Farm Assistance Act, The Prairie Farm Income Act and The Wheat Acreage Reduction Act.

production which were contributed by other industries. It is desirable to exclude duplication from both sides of the account not only because it builds up an exaggerated total, but also because most of our income estimates are based on commercial sales which automatically excludes interfarm transfers. Since the gross farm income estimates are arrived at in this manner, farm operating expenses must be on a comparable basis and should include only those amounts for expenses which farmers paid outside of the farming industry. For this reason, the 1946 prairie census schedule was changed so that expenses paid to farmers, and to non-farmers, could be obtained separately.

Any commodity sold to someone outside the group will obviously yield income to the group. This is the principle involved in determining the first item in Table II, namely, cash income from the sale of farm products. Essentially this is, for each commodity, merely the quantity sold valued at the farm price. Where possible the amounts reported sold through market channels are used. Thus, in the case of grain, marketings of farmers as reported by the Board of Grain Commissioners are taken as the quantities sold; live stock marketings are obtained from Department of Agriculture reports which give sales to packing plants and stock yards together with exports.

In many cases, however, the whole of each commodity does not go through such well defined commercial channels. It is necessary to obtain in addition the amount which farmers sell locally, that is, to small dealers or directly to consumers. In some provinces the local sales of farm products comprise a large percentage of the total farm income. They include: sales of farm animals to local butchers, the value of animals which farmers slaughter and sell to consumers, the value of eggs, fruit, vegetables, firewood, etc., sold in villages, towns or city markets. Another item, of lesser importance in our economy, is the income received by farmers from the sale to other farmers of products which the latter consume. This item, together with local sales and commercial marketings, give the total of the final sales figure desired. In order to round out our estimates, then, it is necessary for us to have considerably more information regarding the quantities of farm products sold outside of commercial channels.

SUMMARY

In summary, it is considered that, at the present time, we are obtaining estimates of the major portion of the income received by farmers from farm and non-farm sources. Progress is being made in obtaining estimates of the remaining portion received from these sources. In compiling statistics of farm products, emphasis should be placed on obtaining final sales figures and figures of "farm home consumed". Such figures would exclude all intermediate sales. Comparable estimates of farm operating expenses, from which duplicating costs have been eliminated, should also be obtained. We would then be in a position to compile and publish the true total of the net income of Canadian farmers.

I have attempted in this paper to give the mechanics involved in determining the total income accruing to Canadian farmers. For purposes of formulating agricultural policy, the income received by farmers is of general

interest. For administering policy, however, several other, probably still more important steps with which I have not dealt, are required. These steps should be undertaken as soon as possible. We should, for example, be able to obtain farm income by geographic areas such as counties, crop districts or soil types. Just as important, is income by size of farm. Another approach which is probably of even greater interest in determining the economic wellbeing of the farmer, is the obtaining of the distribution of income among farmers. That is, we must know not only the average income, but also the variation about the average. We must know more about the high incomes, but especially more about the low incomes. If this distribution could then be related to localities, and to size or type of farm, we would have a sound basis on which to formulate action for the purpose of raising incomes in the low income areas and the low income groups.

There should and could be comparisons of income, or productivity of farm groups, as for example between areas, and by sizes and types of farm. There should also be a comparison of the income or productivity of these groups with the income or productivity of groups in other industries of the economy. Studies of the facilities or social benefits available to each of these various groups would make other useful comparisons between the groups possible. Logical action based on decisions arising from such comparisons could then be undertaken.

WHITHER RESEARCH IN MARKETING AGRICULTURAL PRODUCTS ?[1]

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In considering where we are going in marketing research, I shall confine my remarks mainly to a suggested program of work for immediate or early attention by the agricultural economists in Canada.

To be practical, the program of work must be fitted to the staff of workers and for that reason must be selective. The work already done in marketing research in Canada is creditable. Proof of its value lies in its use and I think it is safe to say that every study has had a practical application in some marketing problem.

PRESENT MARKETING PRACTICES

During this period of transition from a wartime to peacetime economy, there is much work to be done in the field of marketing of agricultural products. Government intervention during the war resulted in a number of changes in the distribution of food products. Certain traditional trade practices were simplified or discontinued. Limitations were placed on the extension of credit, new techniques in processing were introduced and grades and standards took on a more definite meaning for the public. Many of these changes aimed at economy in distribution. The reduction in cost of marketing, which some of these enforced changes brought about, has been so evident that they are being continued on a voluntary basis by the trade. Others are not so evident, and require research to assess their true value in the marketing function.

Government control of prices, and the payment of subsidies to producers, transporters and distributors of food products served a wartime purpose, but, following the removal of the subsidies, and in the transition to a competitive price economy, the readjustments are likely to be difficult. The agricultural economist should supply impartial and factual information on relative changes in major items of cost, to producers, processors and handlers and suggest compromise price determinations, by means of which interruptions or stoppages in the flow of agricultural products, from producers to consumers, may be eliminated. This assumes that the necessary adjustments in price may not or cannot be agreed upon mutually by competing interests. It is suggested that 1942 be selected for the base period and changes in price returns, marketing margins and costs be related to that period. Since volume has such an important bearing on the income of the producers and distributor of farm commodities, the changes in this factor must be measured from the same base. Another important factor, which must be taken into consideration in the determination of price, is the consumer's capacity to pay. An index of change from 1942 in the level of employment in a market area might provide an adequate indicator of the consumer's purchasing power.

[1] A paper delivered to the 15th Annual meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual meeting of the Agricultural Institute of Canada.

[2] Agricultural Economist, Marketing Service, Dominion Department of Agriculture, Ottawa, Canada

SUGGESTED RESEARCH PROGRAMS

It is suggested that a program of research, as outlined above, be undertaken with respect to farm products which were subsidized through the Agricultural Food Board and that fluid milk be given first consideration.

Rough approximations should be utilized to obtain an overall picture of prices and marketing margins immediately; later refinements of more comprehensive accounting and analysis should follow.

The conversion into price of the subsidy on feed grain, which has been provided under the freight assistant policy, presents a reconversion problem for the agricultural economist. Research is needed on the possibility of applying the export freight rate on western grain when moved to the east, for livestock feeding purposes. If the export freight rate is allowed on grain moved to eastern ports for export, could not a case be made for this rate on grain to apply in the case of exportable bacon?

The forthcoming discussions on tariffs and world trade expansion, scheduled to take place in Washington this fall, will indicate along which lines research will be directed in the next few months. The possibilities of expanded markets for our agricultural products, by a general reduction of tariffs and removal of trade restrictions, are immeasurable. The benefits of freer trade, to Canadian agricultural production and producers, appear so important that the preparation of factual background material on the question demands the best efforts of marketing research workers. Much preparatory work has been done, but more is needed, in order that Canadian negotiators will have at hand all data relevant to the discussions.

International commodity arrangements are closely related to tariffs and world trade expansion. Study of this problem comes within the field of marketing research and will develop when we move from a short to a long supply position in certain farm products. Methods of disposal and wider distribution of surpluses on the home market, through programs such as the food-stamp plan and school lunches, require the attention of the research worker.

Since a large part of the marketing margin between consumer price and producer return is taken up by transportation costs, research in this field from the agricultural viewpoint is overdue in Canada. It would seem that contending interests have had more to do with the establishment of existing transportation rates than the application of the results of scientific research. A study of our customs tariff structure has brought to light many anomalies and discrepancies which, to the research worker, appear discriminatory. It is probable that a study of our transportation tariffs would reveal similar unaccountable and costly restrictions in the marketing of farm products. The effects of changes in freight rates upon marketing methods and market relationships have been so far-reaching that they point the way for research in this field by the agricultural economist.

In days now past the farmer who could not produce practically all the needs of his family from his farm was regarded as lacking in competence. There is a hang-over of this idea, or at least the inference seems to be there, when certain towns and cities are accused of not supplying the greater quantity of their food requirements locally. Yet this trend towards dependence on outside supplies will probably continue. More rapid and

cheaper transportation, advances in food processing, packaging and freezing, are all bound to change the Canadian agricultural map of the future. The principle of comparative advantage in production will become operative to a larger degree, and, unless the plant breeder and soil chemists have something up their sleeves, the quantity of farm products produced locally for certain centres of population will diminish rather than increase.

Although not commercially feasible at present, fluid milk is now being flown by regular trips from Prince Edward Island to the U.S. army camp in Newfoundland. Seedling tomato plants were lifted in Georgia and flown to Ontario for planting this season. Improved equipment and lower transportation rates have shifted apple and grape production to well defined areas and it is a certainty that in the future even the dairy cow will not be as widely distributed over the country as she is at present. I mean that dairy farms will probably increase in size and will be confined to specialized areas best adapted to low cost production of milk. Milk will be shipped long distances in liquid, frozen or dried form. The research worker must be alert to these changes. He must look forward with an adaptable approach to the research problem at hand.

The work that is now being done by marketing research workers in Canada in improved marketing facilities and more rapid water transportation is forward looking. After reading the story of Boxcars Take Wings in the June issue of the *Consumers Guide* one wonders how long it will be before an adjoining airways landing strip will be a requirement in the up-to-date food terminal.

Of less immediate importance is work to be done in a study of the economies and improvements in food quality to be gained by the consolidation of small local cheese factories, creameries, fruit packing and other local food processing establishments. This type of study comes within the scope of marketing research in food management.

In laying out a longer range program of work, the marketing research workers in Canada should study the policies and program outlined by the marketing section in the Report of the First Session of the Conference of the Food and Agricultural Organization of the United Nations, at Quebec, and endeavour to correlate their work with that of the Organization. This report states that marketing is the crux of the whole food and agriculture problem. I believe that the conference recommendations can best be carried out by over-all commodity studies and with more team work among economic research workers, production and market specialists and technicians.

The Notebook Survey

A technique in marketing research which I would like to see used more generally when money and manpower are available, might be described as the Notebook Survey. This method of approach might well be adopted before undertaking any detailed economic survey which is expected to employ considerable staff and time. Its comprehensiveness would depend on the time available. Following this plan, an attempt should be made first to get an over-all picture of the problem and related problems through consultation and observation. Then the need for more detail could be assessed and if required, the more comprehensive survey undertaken.

I would also like to see the notebook survey method given a trial in a main marketing research project on a commodity basis. That is, one man with or without an assistant, would follow through on a single commodity or group of closely related products from farm to market. His would be a roving commission with a notebook. His assignment would be to see how the job is done and study the economic implications. He would observe, compare, consult, read and travel. He would try to find the best way of doing the job and where possible suggest improvement.

He might, for example, be assigned to a study of the four major canning crops, tomatoes, corn, peas and beans. He should be on hand at the time of seeding. He would study cultivation and harvesting methods, visit the processing plants, move with the product to the wholesaler, retailer and to the consumer. He should visit a number of farms, consult production specialists, inspectors, plant managers, technicians and salesmen. He should gather cost and price information at every step in the marketing process. Of course, such a method is subject to many modifications and if the research worker found some segment in the over-all study which needed more detailed study, a more comprehensive survey with additional staff might be made of that phase of the work n the following season. This method should produce a commodity specialist and if he can then help people to understand the economics of marketing vegetable canning crops, he will be making a very worthwhile contribution to marketing research.

WHITHER RESEARCH IN AGRICULTURAL CO-OPERATION?[1]

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PAST AND PRESENT IN CANADA

In attempting to discuss future research in agricultural co-operation in Canada, the logical approach seems to be to review what has been done in the past and consider what remains to challenge the future. To review what has been done presents no difficulty for there has been very little, and so, consideration of what remains becomes more difficult because of its magnitude. After a three year absence from active interest in Canadian Co-operation, and feeling the need of guidance, I enlisted the aid of qualified observers in every province and asked them to suggest what gaps in information on agricultural co-operation might be filled by future research. In reply, eighteeen different projects were proposed as needing further examination. Only a few of these were mentioned more than once. Perhaps the most significant, and one mentioned four times, was the need for research defining the economic role of a co-operative in a community. As one correspondent put it:

> ". . . . . co-operators believe that their particular organization has had a beneficial effect upon the general economy but the grounds for that belief are not too easy to prove."

Co-operators are agreed that one of the main reasons for the establishment of a co-operative in any community is to provide a measure of economic relief from monopoly prices by something more competitive in character. Indeed, co-operative organizers are wary of establishing a co-operative where there is no apparent need. They are usually aware that a great many past failures can be traced to hasty and ill-advised organization. Further research could rightly be done to uncover conditions which warrant co-operative intervention. On this particular point it will be interesting to follow the progress of the Canadian Co-operative Implements Ltd. in the field of distribution and manufacture of farm implements. This company is not the result of an unreasoned hue and cry against the operation of private machinery manufacturers and distributors. The organization was considered and the problem studied for a long time. This in itself is a type of research which may become more prevalent in the future. Continued study will reveal the effect of this organization on western agriculture and perhaps on the farm machinery industry.

Other projects were recommended which cannot be regarded as likely to fill major gaps in information but rather they indicated more immediate concerns which needed attention. Some of those suggested were: poultry marketing by co-operatives, co-operative stores, co-operative medicine, co-operative distribution of fertilizer and farm supplies, rural credit unions, co-operative farming, co-operatives and export trading, co-operative lumbering and the co-operative use of farm machinery. One writer

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

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suggested that a comprehensive review of agricultural co-operatives in Canada, comparable to A. E. Richards' report for 1935[1], should be made for 1946, to enable co-operative leaders to assess their present position and plan for further development. Personally, I feel that the variety of suggestions received indicates that research in the field of agricultural co-operation in Canada will probably be confined for some time yet to particular commodity projects and problems.

Chief limiting factors in practically all research are, of course, funds and personnel. These factors apply more to research in agricultural co-operation than in any other field of agricultural economics. Agencies to direct and conduct studies in agricultural co-operation are few and not too wealthy. At the moment, the Economics Division at Ottawa and the Department of Co-operation and Co-operative Development in Saskatchewan are the only two groups equipped with funds and personnel sufficient to do any work along this line. The universities have not done a great deal and are not likely to undertake anything substantial. The Faculté des Sciences Sociales of Laval University has a research division which has undertaken some minor works in collaboration with the Department of Sociology and the Superior Council of Co-operation of Quebec. Ontario Agricultural College has reported particular projects undertaken as master's or doctor's theses, none of which has been published for general distribution. The Extension Department, University of British Columbia, has assigned field workers in the organization of co-operatives and credit unions in the coast province. No doubt, there are many theses on agricultural co-operation which have been completed, or are under way by students, but these are not likely to be published by reason of lack of funds for printing. Other likely agencies are the larger co-operatives and the various provincial co-operative Unions as well as the Co-operative Union of Canada. This latter organization has plans for a research division but again, lack of funds will delay organization and commencement of work. The Union plans a legal department which will aid in drafting and amending legislation for the provinces and the Dominion. There have been suggestions that the Union could also initiate study and research into co-operative accounting and uniform terminology. The larger co-operatives, if they undertake any research, would not be likely to do it in co-operation as such, but would rather be concerned with the technological aspects of the marketing or production of their own particular commodity.

Situation in the United States

In the United States the situation is much different. So much has been done and is now projected that the criticism has been made that the amount of research already completed in co-operative marketing is all out of proportion to the importance of co-operatives in the national marketing scheme. Such a criticism would have no basis in fact in Canada. Rather, the criticism could be reversed, and read that the importance of co-operatives in marketing and purchasing in Canada warrants a great deal more research than has been done or is contemplated. A recent survey by the American Institute of Co-operation reported 52 projects completed and

[1] "Farmers' Business Organizations in Canada 1935."

published since 1939 by universities alone. Besides these, the Co-operative Research Division of the Farm Credit Administration during the same period produced 12 bulletins, 13 circulars, 127 miscellaneous and special reports, 32 confidential reports and it has 35 to 45 projects under way at all times. I do not suggest that Canadian research in agricultural co-operation should ever reach this mark, but I do think that the importance of co-operative marketing and purchasing should, and probably will receive more attention in the future. A start is being made in Canada. Two studies begun in 1939 have been delayed by the war. One dealt with the co-operative marketing of eggs, poultry and live stock in the Maritime provinces and was undertaken by the Dominion Economics Division. It is proposed now that this study be revised and brought up to date for publication. The other was a most comprehensive study of co-operative purchasing associations in Saskatchewan. The final report will consist of eight pamphlets, three of which are now available, and the remaining five are to be pushed to completion this year. A review study of co-operatives in British Columbia is projected, and a similar study is being considered for Ontario. Research Services of the Department of Co-operation and Co-operative Development in Saskatchewan reports a number of projects recently completed and underway including such topics as: co-operative farm planning, co-operative farm accounting, co-operative live stock feeder associations, and co-operative artificial insemination associations. This summer they are undertaking a study of co-operative vegetable marketing and one on co-operative international trading. Other studies proposed involve rural credit unions, beef rings, cold storage and community centres.

Objective Research Needed

Here then, arises the problem of objectivity in co-operative research. The people of the United States have detected a tendency to emotionalism in their work, and research studies as such lose in value when objectivity is forgotten. It is most difficult for people actively engaged in promotional and organization work to conduct strictly impartial surveys. There is an infection about co-operatives against which there is apparently no immunization. Even the most hardened economists—and I have seen some—can and do fall before the charm when they undertake intensive study of co-operatives. Organizers and promoters may rightly be excused when their writings are influenced by their enthusiasm for the co-operative method.

Research in any line can be of two types—(1) informative and analytical and (2) the problematical, wherein a particular problem is tackled and a practical solution proposed. There are some who think that the first type has been overdone. F. L. Thomsen, in the November 1945 issue of the Journal of Farm Economics[1] thinks this way and calls for a more practical approach. Purely informative and analytical works in agricultural co-operation would seem to be needed in Canada for some time yet, but we should not continue indefinitely as Thomsen thinks the United States has done. Even yet in that country, Thomsen reports, only 18% of 589 marketing projects analyzed were of the direct problem approach type. We, in Canada, must get along with our basic and

[1] "A Critical Examination of Marketing Research."

necessary projects and then proceed to the more practical and satisfactory type of research which tackles a problem and presents an acceptable solution.

The records of the Economics Division at Ottawa include reports from more than 2,000 co-operative associations which do an annual volume of business of over ½ billion dollars. There is every reason to believe that these figures will continue to increase. As they do, increased demands for research will have to be met by government agencies, universities, and by the co-operatives themselves through their national union. These demands should result in co-operative efforts by the agencies named, and thus produce much-needed and useful research which will be available to governments for policy planning and legislation, to the universities for teaching purposes and reference, and to the co-operatives for propaganda and publicity.

WHITHER RESEARCH IN ECONOMICS OF NUTRITION?[1]

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Nutrition is a very new science, and exact standards of the amounts of the various food nutrients required for a nutritionally adequate diet have not as yet been determined. A table prepared by the National Research Council of the United States of recommended daily allowances of calories, protein, minerals and vitamins, has been widely used in Canada. Since "the quantities given were planned to provide not merely the minimum sufficient to protect against actual deficiency disease, but a fair margin above this," and since many figures were admittedly tentative until research would give more exact knowledge, the recommended allowances were in some cases much higher than were considered necessary by some nutritionists. Physical examinations made in conjunction with dietary surveys have failed to show defects in those whose intakes of certain nutrients were considerably below the recommended allowances. The Canadian Council on Nutrition in 1945 suggested lower amounts per person of most nutrients for use in estimating, for the country as a whole, supplies of nutrients which would be adequate but not excessive. Those recommendations were influenced by the lack of knowledge as to the benefit of harmfulness of large amounts of certain nutrients, and by the consciousness of the present shortage of food.

Neither the United States National Research Council allowances nor the recent Canadian figures were meant to be used as fixed standards against which the intakes of nutrients by individuals could be measured, since it is recognized that ndividuals vary considerably in their requirements.

Much basic research must be done in determining the minimum and optimum needs of many representative persons. When enough of such tests have been made standards may be set up for individuals. (These will not be fixed amounts, but the range of variation for individuals of different classes may be definitely stated.)

The requirements of a group must be found from the average requirements of its members and the research mentioned above is therefore essential to accurate assessments of the needs of groups. At the present time we must be satisfied to use standards which we know to be subject to change. The tentative nature of present standards tends to discourage the making of dietary studies.

Because of the absence of a satisfactory standard for assessing the diets of individuals or groups of individuals, considerable research work is now underway by nutritionists in Canada and United States to obtain information which will help them to establish such a standard.

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

[2] Economic Adviser, Agricultural Supplies Board, Dominion Department of Agriculture, Ottawa, Canada.

KINDS OF DIETARY STUDIES

Another fundamental problem in measuring the adequacy of human diets is the difficulty of getting information on the actual food consumed. Four principal methods have been employed in dietary studies. We might call the first method that which was used in the inquiry into food consumption levels in Canada, United States and Great Britain, in which the total food produced is calculated, imports are added and exports, wastage and feed and seed requirements are deducted. The remainder is divided by the total population. The result is the average per capita consumption of different kinds of foods. I will indicate later some of the limitations in this method of determining the adequacy of diets of the people of a country.

The second method of making dietary studies is for individuals to keep a record of all the items of food consumed for a given period, say one week. In this type of study the work of analysis of food into its nutrients is great, since the foods listed comprise many different mixtures. Surveys have been made in which the food eaten by each individual was weighed but, owing to the amount of supervision and co-operation necessary, only relatively small numbers of people have taken part. If the food is not weighed its amount must be recorded in servings which may vary greatly in size. By this method an effort is made to obtain a food record for each individual in the study.

The third method is what we call the inventory and purchase method which consists briefly of the weighing of the food in a home at the beginning of a week, having a record made of food purchased or brought into the home during the week, and again weighing of the food in the home at the end of the week. Here again only a relatively small number of families can be covered and in this type of study the food intake of the individual of a family cannot be recorded but only the total family food consumption. In both the second and third methods, several weeks' records scattered over the year are necessary in order to get a picture of the food consumption for a year. The proper number of weeks to be included, and the particular weeks of the year to use, are still unsolved problems.

The fourth is a questionnaire or a check list method and is also on a family rather than on an individual basis. In this method, the housewife indicates to an enumerator the quantities of different kinds of foods used by the family for the week previous to the interview, and the enumerator records these. This information also must be obtained several times during the year. By this questionnaire method a much larger number of families can be covered and it is this method that is being employed in the current study of rural diets in the Maritime provinces. In the Maritime study, information on food consumption is being taken three times from the same families during the year. In connection with this particular study, the enumerators also record the food habits of each member of the family with particular reference to their normal consumption of milk, vegetables, tomatoes and citrus fruits, whole-wheat bread, etc.

In none of the presently used methods of making dietary studies are investigators definitely assured that they are obtaining a complete knowledge of the food consumed by an individual or a family during the year of the study.

LIMITATIONS OF TOTAL PRODUCTION AND CONSUMPTION FIGURES

The figures giving the various quantities of different kinds of foods entering civilian consumption in Canada, which were first prepared in connection with the studies of food consumption levels in Canada, United States and Great Britain, have been a most important contribution to our knowledge of the average food consumption of Canadians. A recent publication, by the Nutrition Division of the Department of National Health and Welfare, shows the estimated average supplies of nutrients apparently used by Canadians.' (Above, this has been called the first method of studying diets). The authors of this publication point out that national average per capita supplies of nutrients would represent the actual quantities of food nutrients used per person only if there was a perfect distribution to each person of a statistical share of each foodstuff.

The authors state further: "The nutrition problem in Canada is not shown by these figures except in those cases where the foods used fall short of the requirement standard used, which means that all people just could not be fully nourished in those nutrients. The nutrition problem is actually one of finding those people who are suffering ill-health by virtue of receiving much less than these average amounts of nutrients, and the solution of the nutrition problem in Canada is the removal of the causes. The extent of malnutrition will depend on the types and amounts of deviations from the national averages in this booklet. These can be ascertained only by direct survey methods, not only for what people are eating, but for what circumstances force them into these eating patterns."

In determing the weighted requirements per person, the authors have attempted to make adjustments for inequitable distribution and losses in storage, distribution, preparation and cooking where figures on these things were available. The report states that these estimates of losses and adjustments for maldistribution are only approximate, and much more information is required. In this field of study extensive research should be undertaken.

MORE STUDIES BY INCOME GROUPS NECESSARY

Studies of consumption of milk, meat, eggs, cheese, etc., which have been made by the Economics Division, have been primarily to assist producers in the marketing of their products. They have, nevertheless, been useful in helping to measure certain aspects of nutrition of Canadian people. They have, for example, shown the direct relationship, particularly amongst urban families, between the quantities of these foods used and the income of the households. Studies of family budgets of wage earners, made a few years ago by the Dominion Bureau of Statistics, have also been useful in determining the relation of income to the consumption of different kinds of foods. Studies of the food consumed by urban households with incomes of $1500 or less in 1939-40 in four cities of Canada has given considerable information on the diets and the deficiencies in the diets of these classes of people. But before we have any adequate picture of the nutrition of Canadians in different income groups, in different sized families and in different geographical areas, much additional survey work will be necessary on the diet pattern to these groups. Until such information is available, we will not know the extent to which there is inequitable distribution of foodstuffs among our urban and rural people.

Preventing Losses in Nutritive Value of Foods

There are economic aspects to the losses in the nutritive value of foods in marketing, in storage, in preparation for consumption and in cooking of foods. We know, for example, that certain vegetables lose some of their nutritive value when exposed for a considerable time under unfavourable conditions in a public market, in a wholesale warehouse or in a retail store. We know that the most approved methods of cooking vegetables will retain more of their valuable vitamins than the older methods of cooking. We know too, that in the processing of foods of various kinds a large part of the original nutrients can be retained when proper methods are used. It may cost little if any more, and in some cases less, in the route from the producer's field or stable to the dinner table to employ methods which retain the original nutrients of the products, but we need much more light on this important subject.

Farm Families Should Have Nutritious Diets

Most farm families can have a diet which is nutritionally adequate because they can produce most of the food commodities which make up such a diet. We hope to know much more about the diets of rural people than we do now, as our rural diet investigations are completed. If we find that these diets are deficient we should undertake studies to learn how to make them adequate and the costs of doing so, so that this information can be made available to farm families to help them correct their diet patterns.

Spending Food Dollars Wisely

We know from dietary studies that some urban families obtain a better diet than others, for the same expenditure of money. This is an economic aspect of nutrition that needs more investigation in an effort to help the lower-income families in their problem of how to spend their food dollars most wisely.

Production of Foods of High Nutritive Value

There is considerable interest in the production of varieties of food plants which have high nutritive values. Some kinds of wheat, for example, are higher in vitamin B, some varieties of tomatoes and apples are richer in ascorbic acid than are other kinds or varieties. Whether or not it would pay for farmers to grow varieties with the higher vitamin values depends on their relative yields per acre and other economic factors.

Using Family Allowances for Better Foods

In Canada, and in many other countries, family allowances plans are now in effect to assist low- and medium-income families with children to increase their purchasing power. This added purchasing power should result in better diets, especially if the recipients of the allowances are educated to the importance of using the funds provided by governments to buy foods which will satisfy the physical needs of their growing children. To what extent this added purchasing power is being used to improve the nutrition of these children would be the object of a useful research project and could be the basis of an educational program on nutrition.

Floor Prices and Food Patterns

It is price that largely determines what a farmer produces; whether wheat for human consumption or barley for hogs, whether dairy products or sheep products, whether carrots or cabbage. Through the mechanism of floor prices the production of a crop or animal product can be encouraged or discouraged. Any government which has authority to set floor or minimum prices, to buy and sell food commodities and absorb any losses between buying and selling prices, can do much to determine the food pattern of the people of that country. People in general like to eat nutritious foods such as milk, meat, eggs, fruits, and vegetables, and generally speaking they will buy them if they can be obtained at prices within their pocket books. If a government is prepared to take care of the losses between buying and selling prices, every family in a country can be given the opportunity of obtaining an adequate supply of foods of high nutritive value and at the same time the producer can be paid the prices which will make their production profitable.

Lowering Production and Marketing Costs

Any reduction in the costs of production and marketing of foodstuffs should contribute to better nutrition, because the savings in costs are not only of importance to producers who are likely to be the first to benefit, but they will eventually also help consumers by giving them food commodities at more attractive prices. How to lower the costs of production and marketing is, of course, a most important field of economic investigation.

Food Problems of World Largely Economic

One of the primary reasons why so many people of the world are chronically ill-fed is because it has not yet been profitable to bring under cultivation for food production the land areas of the world which are still undeveloped. Nor has it been sufficiently profitable to food producers to drain or irrigate sufficient additional land, to use better cultural methods on present crop land, to employ more and better machinery and more commercial fertilizers in order to raise the yields per acre. If, and when, the nations of the world where malnutrition is common, and in some cases universal, obtain the purchasing power necessary to make it possible for their people to pay for foods at a price that will encourage the opening up of new land for productive purposes and the increasing of yields on present farm lands, the world's food producers will supply the food to satisfy the hunger and to eliminate malnutrition in these countries. I recognize, of course, that there is a limit to the amount of land in the world which can be used for food crops, and that the extension of scientific and technical knowledge of food production and marketing will help to adequately feed the world, but the main problem is economic. Most of the malnutrition in North America, in Europe and in Asia is due to poverty. Economic research on a world scale would contribute greatly to the solution of this stupendous problem. Most, if not all, the wars between nations have been because of real or imagined economic differences between these nations. The elimination of war and the fear of war rests in a very large measure on the elimination of want and malnutrition.

AGRICULTURAL PRICE POLICY[1]

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All countries have had definite price policies for farm products during the war years. Some of the practices prevailing during the war years may be expected to be carried over to the post-war period. It must be recalled that regulation of prices of farm products in some countries did not start with the recent war.

The price policies of different countries in the pre-war period, during the war, and now proposed for post-war years, varied in the past and will vary in the future, if present proposals prevail. A comparison of some of these regulations in different countries is one of the first purposes of this paper.

The two countries whose price policies have a definite influence on Canada are Britain and the United States. The reasons why this is so needs no elaboration before this audience. Yet it may be well to recall that there have been times when the United States have been important to agriculture, and to the nation as a whole, both for exports of the surplus farm products that we do grow, as well as for the imports, which because of climatic limitations, are not produced locally. Exports south tend to be spasmodic while imports from the south are more or less regular. With Britain, trade is largely one-way traffic as far as farm products are concerned. Yet the nature of the one-way traffic depends upon the price policies for agriculture that are carried forward in Britain. To a greater degree perhaps the price policies for agriculture in Canada depend upon how the problem is treated in the United States. The fiscal policy of Canada, from the Repeal of the Corn Laws a century ago, to the present, has been largely the result of the fiscal policies of both Britain and the United States. This is simply because it takes two or sometimes three to make a bargain.

The first necessity is to compare the price policies, past, present and proposed of the three countries.

BRITAIN'S AGRICULTURAL PRICE POLICIES

Recent regulation of prices of farm products began in the early twenties with the bonused expansion of beet growing. This was followed in 1932 by bonused wheat growing and, before the outbreak of war in 1939, the Minister of Agriculture of the time claimed that all staple farm products enjoyed some measure of price insurance.

From 1932 to 1938 British wheat growers were guaranteed a farm price of $1.25 per bushel or better. During that period the average farm price in Canada was 65 cents per bushel. The proposal is to pay domestic wheat producers of Britain $2.00 per bushel for the current crop.

[1] A paper delivered to the 15th Annual Meeting of the Canadian Agricultural Economics Society, held at Macdonald College, Quebec, June 24, 1946, in conjunction with the 26th Annual Meeting of the Agricultural Institute of Canada.

[2] Professor and Head, Department of Agricultural Economics, Macdonald College, Quebec.

Just what the future price policy is to be is rather hard to estimate except that it proposes to pay enough to the domestic grower to keep him at it and, at least according to some authorities, buy the necessary imports at the lowest price possible, which has been their custom for around a century. It is proposed to provide guaranteed future prices for farm products produced domestically, provided a certain degree of efficiency is reached. Failing a certain standard of efficiency the powers that regulate prices reserve the right to eject the farmer from his business. This may be something like the possibility of a lawyer losing his gown for conduct unbecoming to the profession. We may suspect that it may happen about as often.

The policy of a two-price system prevailed in Britain before the war, during the war, is now prevalent and is proposed for the future. The philosophy of this plan has been clearly set forth by Geoffrey Crowther, editor of the London *Economist*—

"A man-hour of work on the British farm produces less in money value than a man-hour of work in British industry. From the purely economic point of view, we should put our labour where it will produce most, and we should buy our food from where it costs least . . . . In a country where industry so greatly outweighs agriculture, cheap food is a great boon . . . . Agricultural policy in this country should not be based on economic considerations alone, but it should not ignore them . . . . It is a national interest that imported food should be as cheap as possible . . . . The British farmer would have nothing to fear from this freedom of imports. He could always sell on the market, however low it fell, in the knowledge that his deficiency payment would be all the larger. On the other hand, freedom of import allows the British consumer to get the other half of his food supplies at the lowest price to which world-wide competition will drive it . . . . And since deficiency payments would not enter into retail prices, the cost of living would remain at rock bottom, with all the advantages that brings to the standard of living, and, through its effects on wages, to the cost of production of English industry."[1]

This is the two-price policy that prevailed in the pre-war period and apparently has some support for the post-war era.

THE UNITED STATES

The United States also favours a two-price policy. But is it to be used quite differently from that of the British system. It is not the domestic consumer that is to be the beneficiary in the plan proposed, but rather the foreign consumer, whoever he might be. The two-price system as proposed for the post-war period is that the small surplus that of necessity must be disposed of on the world market, must not be allowed to depress food prices in the domestic market.

While Britain proposes a two-price policy which must not permit prices needed to keep domestic farmers producing to apply to the other half of imported food, the United States proposes to prevent the small fraction of a surplus to depress domestic prices.

[1] Crowther, G., Prosperity and Cheap Food, *Farmers' Weekly*, March 16, 1945.

There is no mathematical limitation to the variation in proposals of the two-price system. The source of limitations, if any, is from those who supply public funds. This is not a serious source of limitation, as taxpayers usually utilize so much energy trying to avoid the taxes that they know they pay, that they have no energy left to attack the more subtle problem of paying those taxes of which the incidence may be a bit uncertain.

It is not hard to understand why the two-price system is applied in different ways in Britain and the United States. One is an import country for food supplies and the other has a small surplus, that is, small in comparison to the domestic market. Hence both countries may be said to follow the system that will be, for each, the most economical from the point of view of the public purse—or taxpayer. Neither of these two-price policies are to be compared with a lower price for those who otherwise cannot afford to buy, which policy is generally supported by producers.

CANADA

A comparison and contrast of Britain and the United States is illuminating when considering the price policy of Canada regarding farm products. It is my contention that Canadian fiscal policy is the result of the respective policies of both Britain and the United States. Prices of farm products depend to a great degree on what these two countries do in regard to prices, for two reasons. One is that these two countries are our best customers and the other is that Canada with 60 million acres of land in field crops and upwards of 10 million of pasture and only 12 million people—is a surplus country of food products in a much larger way, proportionally, than is the United States.

Canada is now, and has always been, trying to cater to two markets, namely, Britain and the United States, in the export of farm products. Now with the two price policies outlined above what policy *may* Canada follow? It is not an easy matter to establish a price policy for Canadian farm products.

The problem is made more complex by the climatic limitations of Canada. Not only have we a surplus of farm products generally but it is also necessary to produce and sell a large volume of those things which it is climatically possible to grow in this northern region, but also to produce enough of a surplus to exchange for many articles of diet, such as citrous and tropical fruits, that we cannot produce yet consume in great amounts.

The inability of such a country situated as far north as Canada to follow a self-sufficing system, is conceded and needs no elaboration. Yet, this condition stresses the importance of a price policy as well as increasing the importance of international trade.

Canadian people—three-quarters of whom are not farmers—expect that agriculture as an industry must cater to the world market in a large way. The chief market, as we have seen, insists on a policy of cheap foods. The idea of charging more for food in the domestic market than world prices has been suggested, but never taken very seriously. The proportion of farm products exported is too great to make this feasible. Past practice has been to let world market prices establish domestic prices whatever

economic position that left the industry. During the war-period contract prices came into practice. The post-war period proposes to continue that general policy plus floor and ceiling prices.

PRODUCING FOOD ON ORDER

Contract prices work fairly satisfactorily provided that there is some equality in bargaining power, and that some flexibility in prices is provided. The equality of bargaining power depends largely on the volume in prospect. In any event contract prices entail some suggestion of horse-trading in the sense that negotiation may require a certain compromise or *give* as well as *take*. Let us remember that negotiated prices are not entirely a new development as the record of adjusting prices for fluid milk amply illustrates.

FLEXIBILITY

It is hard to preserve a degree of flexibility in negotiated prices that will avoid shortages and surpluses. Recent experiences have demonstrated the possibility of regulated prices developing shortages while the possibility of regulated prices piling up surpluses have occurred within the memory of some of us. It would appear that we have not allowed sufficiently in recent price regulation for the simple economic axiom; the cure for high prices is high prices and the cure for low prices is low prices. In other words, regulation of prices means regulating supplies. It is hard to have low prices and plenty for any permanent period. We generally concede this in other goods but are loath to allow this simple philosophy to apply to food. Naturally, we want cheap food and this topic may come up later if time permits.

Price flexibility must be maintained for two main reasons. One is the need for allowing for improved technique in production. This is usually kept in mind. The other, more temporary perhaps but very important in a country such as Canada, is seasonal flexibility. This seasonal flexibility has not been well maintained under price ceilings. In some instances it may have worked well. Yet in some it has resulted in making the marketing more irregular than usual. This is noticeable in live stock. The seasonal shortage of beef is an example that needs no discussion at the moment as it is too familiar to all. The marketings of hogs is an example that may have escaped notice. All familiar with the number of hogs coming forward monthly know that it required a higher price from June to September than from November to January to keep supplies fairly regular. With our climate this is understandable. Yet during the past few years, with contract prices, the November price has run to about the same and sometimes higher than the June price of the same year. This was due to new bacon contracts being made in the month of October. With increasing prices, it has been possible to have higher prices in November than in June. If this continues for sufficient time fewer will be fed in the winter months and supplies will be irregular. The provision of flexibility provided for in the first contracts appear to have been pigeon-holed, and supplies have become less regular. This has been partly due to methods of breeding in Western Canada. Yet it has developed a problem that will require time to readjust.

Price Policies

Price policies may take a variety of forms. Interferences with price include the following:

1. Customs tariffs
2. Bonuses
3. Sanitary regulations
4. Wage regulations
5. Quotas
6. Cartels
7. Currency manipulation
8. Ceiling prices
9. Floor prices
10. Contract prices

Probably this list is not complete. There is no need to discuss all these forms. Yet it is necessary to list them to show that price competition may be, and is, interfered with in many ways.

With prices *arranged* or *administered*, one may use the word liked best, the struggle becomes one of trying to get into the production of those goods that have the highest ceiling. Men's shirts and butter are two recent somewhat similar examples. The raw material for both butter and shirts could be turned into products that offered more profit.

PROBLEMS IN PRICE POLICIES

The Department of Labour, Ottawa, in a release of May 6, 1946 sets forth the major difficulty in formulating price policies for agriculture. This release compares prices of butter, eggs, sugar, bread and milk for March, 1919 and 1946.

Commodity	Price	
	March, 1919	March, 1946
	¢	¢
Butter, per lb.	58.0	44.7
Eggs, per doz.	54.6	43 8
Sugar, per lb.	11.9	8.6
Bread, per lb.	7.9	6.7
Milk, per qt.	13.7	10.5

On the same page it is pointed out that wages being paid to-day in the main occupational and industrial groups are the highest in Canada's history.

One page poses the problem. Wage-workers want high wages and cheap food. Farmers favour free labour and high prices of farm products. Some modification of this latter sentence appears necessary. Grain growers favour high grain prices. Feeders favour cheap feed for their live stock. It is hard to satisfy everybody.

Cheap food is a desirable aim. This is an advantage to the farmer as he now buys such a large part of his food. This comes about with specialization in farming. Not only is the farmer interested in cheap food for himself, but also in cheap feed for his live stock that is purchased in ever grêater and greater proportion. In Canada out of a total of $462 million farm expense in 1940, $63 million was for purchased feed. Only one other item exceeded this total which was labour, including value of board, $84 million. Quebec and the Maritime Provinces spent much more on pur-

chased feed than on labour. Will or should the freight subsidies on feed be continued is a question in price policy. Cheap food and prosperous agriculture may go together. How is this possible? By increasing output per farm, and per man. By fewer farm workers producing more. Not by harder work. Many farmers working for themselves *may* now put in two 40-hour weeks per week. They may do this without interference as all general labour regulations specifically exempt farmers from their provisions. The better way to bring this about is by better organization and management. This may require larger farms in some areas. People do not like this suggestion. Many assume that the way to get cheap food is to have more farmers. This is a mistake. If this were true, then the question of why Canada is supposed to furnish so much in the fight against famine becomes somewhat perplexing.

SUMMARY

Time limits the elaboration of these points. Yet two more must be mentioned. One is the question of why the Atlantic Charter mentioned raw materials as the only materials that should be free of access to all people. The other one is how will the export of Canadian farm products be influenced by the present separation of the surplus food area of Germany from the densely populated deficit area? These are perplexing problems in price policy. Is it to be conceded that the only products for which freedom of trade is proposed are *raw* products? Must the feeding of the bulk of the population of Germany be largely a responsibility of North America, and for how long?

Limitations of time have prevented attention to countries other than the three in a comparison of price policies. Other countries might be mentioned. In the pre-war period the Argentine was reluctant to enter into any international price agreement. It was looked upon at that time as fearless of international competition. A recent report records that it is now proposing even stricter regulation than prevailed under any European dictatorships.

European dictatorship planned to make Germany the industrial star of Europe with satellite states inferior constellations supplying the raw materials. One plan of the Allies was to de-industrialize Germany. This plan was unwelcome in Germany and described as an endeavour to reduce that country to a potato patch. Are we to conclude that there is a definite admission that other industries are to continue to be more prosperous than agriculture? If so, then I submit that this conclusion may have, and should have, a salutary influence on Canada's export food policy, and our share and responsibility in relieving scarcity of world food supplies.

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THE EFFECT ON CARCASS EXCELLENCE OF PROPORTION OF ANIMAL PROTEIN IN THE HOG DIET[1]

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Most modern recommendations regarding the make-up of rations for swine emphasize the inclusion of protein of animal or marine origin. The minimum quantities specified seldom are less than 20% of the total protein. Experimental evidence supporting such an allowance is neither unanimous nor too convincing in the light of present knowledge of feeds and of swine requirements. Indeed it appears that what originally may have been recommended as desirable has in some instances later been interpreted as a necessity. Mitchell (1943) in his review of the need for animal protein in swine and poultry rations, points out that most of the instances where improved feeding value of rations has resulted from the inclusion of animal proteins can equally as well be explained on the grounds of minerals and vitamins as on the basis of amino acid supplementation.

With the severe shortage in Canada of feeds of animal or marine origin during the war years, the question of their minimum use was of special interest. Not only are matters of rate of growth and of feed efficiency of importance, but also the possible effect on the characteristics of their carcasses intended for bacon must be taken into account. Accordingly a feeding trial was conducted to obtain data relative to these questions.

METHODS OF INVESTIGATION

In order to establish the levels to which the proportion of animal protein, represented in this test by tankage, may be reduced from a "normal" of 20%, this feed was replaced by linseed oilmeal on a nitrogen equivalent basis so that 4 rations contained respectively, 20, 10, 5 and 0% of protein from animal origin. In addition a fifth group was included in which wheat germ was employed as a protein source.

Pure-bred Yorkshire pigs weaned at about 56 days of age, and started on test at initial weights of approximately 45 pounds, were used.

The basal feed for all pigs was No. 2 feed barley. This feed comprised from 81 to 85% of the ration of pigs up to 100 pounds in weight (see Table 1), but after that time the proportion was increased to approximately 90% These proportions gave a protein content of the growing ration of 16% and of the fattening ration of 13%.

[1] Contribution from the Department of Nutrition, Faculty of Agriculture, Macdonald College, McGill University, Quebec Journal Series Number 218

[2] Professor of Nutrition.

[3] Lecturer in Nutrition.

Three percent of a mineral mixture was included in all rations. It consisted of:—

28 lb. feeding bone meal
47 lb. ground limestone
25 lb. iodized salt
4 oz. ferric sulphate

Until they weighed 100 pounds, the pigs were fed three times daily in amounts limited only by appetite. From then on the pigs were fed twice a day. For feeding, the allowance of meal mixture was placed in feed troughs and about three times its weight of water poured over it. Until the pigs weighed 100 pounds, they received 15 cc. of cod-liver oil per day. Pigs were confined to individual feeding pens throughout the test.

RESULTS

Effect of Level of Animal Protein

In Table 1 is a summary of the effects on pig gains, on feed efficiency and on carcass excellence of varying levels of animal protein in the ration.

TABLE 1 —SUMMARY OF EFFECTS ON PIG GAINS, FEED EFFICIENCY AND CARCASS EXCELLENCE OF VARYING LEVELS OF ANIMAL PROTEIN IN THE RATION

Ration / Description	6 Tankage 6 Oilmeal 3 Minerals 85 Grain * * * Animal Protein 20%	3 Tankage 12 Oilmeal 3 Minerals 82 Grain * * * Animal Protein 10%	1.5 Tankage 14 Oilmeal 3 Minerals 81.5 Grain * * * Animal Protein 5%	0 Tankage 16 Oilmeal 3 Minerals 81 Grain * * * Animal Protein 0%	0 Tankage 8 Oilmeal 10 Wheat germ 3 Minerals 79 Barley * * * Animal Protein 0%
No. pigs	24	24	24	24	24
Initial wt. lb	45.4	45.3	44.3	45.6	45.6
Feed eaten lb	650	639	636	646	596
Days fed	108	111	110	110	101
Daily gain, lb	1.46	1.38	1.40	1.40	1.54
Daily feed, lb.	6.0	5.8	5.8	5.9	5.9
Adjusted gain, lb	1.42	1.40	1.42	1.40	1.54
Carcass data—					
Length of side in	30.0	30.0	30.1	29.9	30.2
Depth of neck fat, in	1.78	1.75	1.72	1.76	1.75
Lean in rasher %	42.0	41.7	40.7	40.9	42.3
Area pork chop sq. in.	4.9	5.0	4.9	4.8	5.2
Score	74	76	78	75	82
% carcasses—Grade A	46	67	46	50	50
Grade B	50	33	50	50	50

Before commenting in detail on the data of this table, it may be well to point out that the averages of gains and of feed consumption include pigs which were restricted in feed with the intention of reducing their daily gain. This does not affect the comparisons between the protein levels since there were in each lot equal numbers of pigs restricted as compared to those on full feed. It does, however, tend to reduce the average gains of the test. It may be stated that the average daily gain, over the entire feeding period, of the pigs full-fed throughout was 1.52 pounds per day, while the gain for those that were restricted during the fattening period, averaged 1.35 pounds.

One of the first things to be noted in this test is that the reduction of the animal protein, from 20% to 0%, has not appreciably affected the rate of gain of the pigs, nor has it affected feed consumption, or feed efficiency. Statistically, the difference between 1.46 pounds per day gain on the 20% animal protein and 1.38 pounds per day gain on the 10% animal protein is just on the level of significance with odds at the 5% point. However, the daily gains of the 5% and 0% animal protein groups were not statistically below that of the lot fed 20% protein.

It will also be noted that the reduction of the animal protein proportions has not affected the length of the pig as measured by length of side of the carcass; nor has it affected significantly, the depth of fat or the percentage of lean in the carcass.

In connection with the carcass grade, the group receiving 10% of animal protein has shown a larger proportion of grade A carcasses than in any of the other 3 lots, and it is obvious, therefore, that this cannot be the effect of animal protein. In fact, ration differences have not affected average carcass grade or score in this test.

The inclusion of wheat germ as a substitute for the tankage has actually resulted in increased rate of gain at no increase in feed intake. Nor was there any evidence of a fatter carcass than was produced on the animal protein lots.

These findings are not in accordance with the view commonly held of the desirability of the inclusion of some protein of animal origin in the bacon hog ration. From the standpoint of rate of gain, the wheat germ meal, as a supplement to oilmeal, gave a response significantly greater than did tankage. This might be interpreted as a protein supplementary effect with oilmeal greater than that of tankage. The question of course may be raised as to whether or not "wartime" tankage is the equal of pre-war meat meal. The fact remains, however, that in this test the pigs receiving a wheat germ-oilmeal protein supplement made more rapid and more efficient gains than others on either oilmeal plus tankage or on oilmeal as the protein supplement.

CONCLUSION

Data from this test involving 120 pigs fails to indicate that present tankage up to 20% of the total protein enhances the nutritive value of the bacon hog ration carrying 15% crude protein in which oilmeal or oilmeal plus wheat germ comprise the only other source of protein excepting that of the basal feed, barley.

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A METHOD OF ESTABLISHING RUST EPIDEMICS IN EXPERIMENTAL PLOTS[1]

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In any cereal or other crop-improvement programme where disease resistance is considered, it is essential that the plant populations under investigation be subjected to epidemics of diseases, particularly the various rusts, to facilitate the selection of resistant plants as well as to study the inheritance of disease resistance. Rust epidemics do not occur naturally every year with the same intensity and, even under conditions of a severe epidemic, only a few of the known physiologic races may be present in any one district. In order to select plants resistant to any given rust it is desirable to use all the races that may occur in those regions where the new variety may be grown. A method, therefore of inducing rust epidemics artificially is of great importance.

REVIEW OF PREVIOUS METHODS

As early as 1920 Durrell and Parker (1) described a method of increasing rust inoculum in the greenhouse and inoculating experimental plots in the field. They found that, in the greenhouse, "young plants would produce spores for a week or 10 days, while older plants would bear spores for a month in great profusion". They used older plants, therefore, to increase the inoculum for field inoculations. They tested several methods of field inoculation, including spraying a spore suspension on plants with a knapsack sprayer and dusting dry spores on plants thoroughly moistened with a fine mist from a sprayer. The latter method, they found, gave the best results when rust spores were applied in "large quantities at intervals of 1 or 2 days during that part of the growing period when the plants were making rapid vegetative growth".

The method developed by Durrell and Parker (1) appears to have been overlooked or not adopted by subsequent investigators. At least, no further reference to the method has been noted. It also remained unknown to the author until after a similar method had been developed at Winnipeg.

In 1924, Stakman and Aamodt (3) described a method of establishing an epidemic of wheat stem rust in Minnesota. They infected with stem rust common barberry bushes growing adjacent to the wheat plots. They also sprayed the border rows, after sunset or on wet cloudy days, with a suspension of rust spores and kept the sprayed plants under bell jars for 40 hours. In addition, they placed between the rows of their plots wheat seedlings grown in pots in the greenhouse and heavily infected with stem rust. Mackie (2), in California, apparently not succeeding with similar methods, used late sown wheat to initiate infection and then irrigated his plots to induce the development of rust and some other cereal diseases. In Kenya, Thorold (4) described a method somewhat similar to that of Stakman and Aamodt (3). He planted his so-called "surround" rows at

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least 10 days earlier than the experimental plots and made his first inoculations on plants in the seedling stage, the rust spores being spread over the leaves with a flattened needle and the plants then covered with bell jars for 60 hours. Zehner and Humphrey (5) introduced the method of injecting spores into cereal plants with a hypodermic needle. This method gave good infections regardless of the air humidity and, consequently, there was no need for the bell jars or any other humid chambers. It was, however, a slow and tedious method, requiring many days to inoculate border rows totalling several miles in length.

With the increase in area devoted to the growing of hybrid material and to various rust experiments, improvements in the method of establishing rust epidemics became desirable and, accordingly, various tests were made at Winnipeg during the last 10 years to devise a simpler and more efficient method. This method is described in the following paragraphs.

THE IMPROVED METHOD

Production of Rust Inoculum in the Greenhouse

In the laboratory, where physiologic specialization of cereal rusts is being studied, small amounts of rust spores of different races are collected from the differential hosts and stored separately in glass vials in a refrigerator. It has been found that dry spores stored at a temperature of from 0° to 3° C. will remain viable for as long as 12 months. For the production of rust spores for field inoculum, plants of a susceptible host are grown in well fertilized soil in 6-inch pots with 3 plants per pot. When in the shot-blade stage, the plants are inoculated by means of a small duster (Fig. 1) with urediospores diluted with talc, or any other finely-ground inert material, at the rate of 1 part of spores to 10 parts of talc. Inoculation may be made with spores of a single physiologic race or a mixture of races. After inoculation the plants are sprayed with a fine mist of water and left in a moist chamber for 24 hours. An inexpensive and convenient moist chamber can be made by covering a frame built of 1 x 2 inch lumber with heavy cotton sheeting or cardboard. As soon as the inoculated plants have been

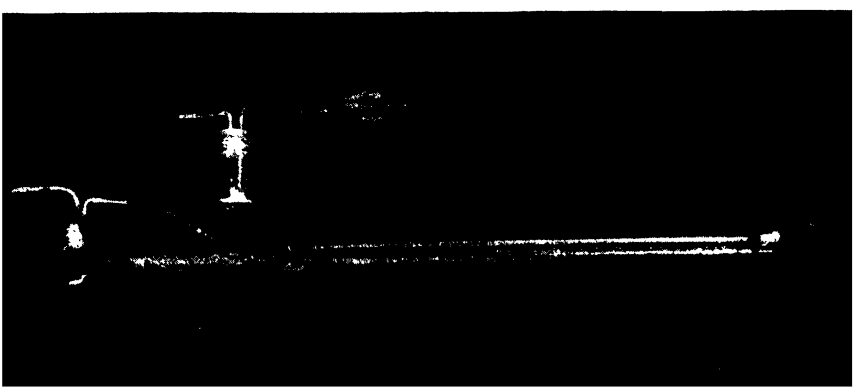

Figure 1—Top—A small duster used for rust inoculation in the greenhouse.
Bottom—Similar duster with a 30-inch handle for field inoculations

placed in the chamber, the inside and outside of the latter is thoroughly wetted. The temperature of the greenhouse is then allowed to drop to 10° to 15° C. Under these conditions a very heavy infection is obtained. The drop in temperature is necessary to ensure condensation of moisture on the plants, and the lower temperature (about 15° C.) is favourable for the germination of the urediospores.

After the inoculated plants are removed from the moist chamber, they are kept in a moderately cool greenhouse and as soon as they start heading the spikes are cut off to prevent breakage of the plants and also to lengthen the life of the infected leaves. When rust infections develop the spores are collected every 2 or 3 days by inclining the infected plants over a smooth sheet of paper and then tapping lightly on the stems with a short stick to shake off the mature spores. A hundred pots of well grown plants kept under favourable conditions will yield over 400 cc. of rust spores.

FIELD INOCULATION

Prior to the development of the present method, field inoculations at Winnipeg were made partly by transplanting plants heavily infected with a particular rust in the greenhouse, but mainly by the injection method developed by Zehner and Humphrey (5). The injections were usually started when the plants were in the third or fourth leaf stage, several plants being inoculated in every few yards of the row. This method always resulted in good infection at the point of inoculation, but only the leaf that was in the sheath at the time of injection, or a part of it, became infected. These infection centres, under favourable conditions, were sufficient to spread the rust throughout the border rows and the plots, but under conditions that were not conducive to a rapid spread of rust the injections might have to be repeated 2 or 3 times. Considering that, at Winnipeg, the total length of the border rows to be inoculated usually exceeds 10 miles, the establishment of rust epidemics by this method required a great deal of work.

In Nature rust spores either settle down from the air or are carried down by rain showers and, when a spore shower is followed by dews or muggy weather, a heavy rust infection results. Accordingly, the dusting of rust spores over the border rows was tested in comparison with the following alternative methods: *(a)* spraying a spore suspension on the plants with a knapsack sprayer, *(b)* transplanting plants heavily infected in the greenhouse, and *(c)* injecting plants with a spore suspension by means of a hypodermic needle. Several tests with all 4 methods were made and in each instance dusting dry spores gave the best results. Naturally, when an application of rust spores was followed by hot, dry, and windy weather for several days, very little or no infection developed, but if applied on a calm evening after sunset when plants were becoming damp from the formation of dew, very heavy infection resulted.

The first year the method of dusting dry spores was used, it was found that a large quantity of spores was required to inoculate all the border rows. A modification of the method was suggested as a result of tests made by Brown[1] on the effect of diluting rust spores with talc. He found

[1] Unpublished data by A. M. Brown, Dominion Laboratory of Plant Pathology, Winnipeg, Man.

that a mixture of 1 part of spores to 10 parts of talc by volume gave as good infection as the spores alone. Observations made subsequently on plants dusted with this mixture revealed that the talc particles acted as nuclei for the condensation of water vapour from the air. The leaves of a plant dusted with talc powder became covered with minute droplets of water over the entire surface while undusted leaves had much larger droplets mainly on their edges. Talc, therefore, acts not only as a diluent of spores but, by virtue of its moisture adsorbing capacity, it enables a higher percentage of the spores to germinate and penetrate into the tissues of the inoculated plants.

The improved method, consisting of dusting rust spores mixed with talc at the rate of 1 : 10 over the border rows on a clear calm evening after sunset, has now been used at this laboratory for several years with very good results. The inoculum is applied with a small duster (Fig. 1) suspended on a piece of broom handle about 2 feet long so that plants in the border row in their third or fourth leaf stage can be dusted without bending down. One person can inoculate about 3 miles of border rows in an hour, depending on the speed at which he walks. With thick and leafy border rows, one dusting results in a sufficiently heavy infection to ensure a good epidemic.

SUMMARY

A simple and reliable method of establishing rust epidemics in experimental plots is described. The method consists in dusting the border rows with dry urediospores diluted with talc in the proportion of 1 part of spores to 10 parts of talc. The spores are produced in the greenhouse on large well-developed plants growing in 6-inch pots with 3 to 4 plants per pot. Every 2 or 3 days the spores are collected by shaking heavily infected plants over a smooth sheet of paper. The heaviest infection was obtained in the field when inoculations were made on clear calm evenings as the dew was beginning to form.

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DIGESTIBILITY STUDIES WITH SWINE

II. THE DIGESTIBILITY OF GRAINS AND VEGETABLE PROTEIN CONCENTRATES AT DIFFERENT STAGES OF THE GROWING AND FATTENING PERIOD[1]

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In the first paper of this series (3) the coefficients of digestibility of the nutrients of a number of grains and concentrates were determined with swine at various periods between 40 kilograms and 150 kilograms in weight. It was found that the digestibility was not affected by the stage of growth. Crampton and Whiting (1) determined the coefficients of digestibility of feed barley, screenings and feed oats at different stages of the growing period. They used a lower initial weight, namely about 25 kilograms and a lower final weight, namely about 90 kilograms. No differences in the digestibility due to the age or size of the pig were observed.

In the present paper the studies on digestibility are continued with buckwheat, rye, screenings, barley and vegetable protein concentrates from different sources. Barley was used as a basal ration with the vegetable protein concentrates. The following 8 feeds were used.

(1) Soybean Oil Meal—Expeller process, Central Soya Co. Reg'd No. 1328.
(2) Soybean Oil Meal—Solvent process, Archer Daniels, Montreal. Reg'd No. 5409.
(3) Linseed Oil Cake Meal—Carpenter's, Hamilton. Reg'd No. 4185.
(4) Linseed Oil Cake Meal—Sherwin-Williams Co., Montreal, Screw Press method. Reg'd No. 3335.
(5) Buckwheat—No. 1 C.E., Silverhull Variety.
(6) Rye—No. 3 C.W. Feed Rye.
(7) Screenings—Ground No. 2 Feed.
(8) Barley—No. 1 Feed Western.

For the digestion trials 8 pure bred Yorkshire barrows were used. They were about 60 kilograms in weight at the beginning of the experiment and about 150 kilograms at the conclusion. The 8 rations were fed to the 8 pigs in 8 periods in a randomized Latin square set-up. The animals and periods were numbered respectively 9 to 16. Each period was 24 days long consisting first of a 4-day pre-experimental subperiod in which the animals were allowed exercise and a standard pig ration. This was followed by a changeover subperiod of 6 days, a preliminary subperiod of 7 days and a collection subperiod of 7 days. The concentrates were fed with barley in the ratio of 1 to 2. The remaining feeds were fed alone. Supplements of salt, vitamin A and vitamin D were given. Rations were fed in the form of a slop.

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PROGRESS OF EXPERIMENT

In the 8 periods there was one feed refusal, namely Animal 10 receiving rye in Period 10. The results of this individual trial were discarded. The remaining pigs of that period and all the pigs in the remaining periods maintained satisfactory health and appetite.

RESULTS

Summaries of the data pertinent to the discussion are given in Tables 1 and 2. Further data are given in Tables 3 to 7 inclusive. Table 3 presents the mean composition of the feeds. Table 4 gives the mean coefficients of digestibility for the individual feeds. Table 5 gives the daily rations; Table 6, the individual coefficients of digestibility for each nutrient for each feed; Table 7, the individual coefficients of digestibility for the vegetable protein concentrates calculated from the mixed rations with barley. In the statistical examination of the data, the method of Yates (4) was used to estimate the missing value for rye in Period 10, in order to apply tests of significance. Detailed analyses of variance are not presented but necessary differences are included in the tables.

DISCUSSION

Table 1 gives the mean coefficients of digestibility for each nutrient, firstly for each period and secondly for each animal. Beneath the individual columns are given the total range from the lowest to the highest values and the necessary differences between any two means. It will be noted that there was little effect of either period or animal. For instance, in the case of the dry matter, the total range with either animal or period was 1.6 absolute per cent. Between any of the Periods 11 to 16 there were no statistical differences. Period 10 was slightly higher than the rest. Period 9 was slightly higher than Period 14. In the case of the animals, No. 10 was slightly lower than the rest and No. 14 slightly higher. Otherwise, there were no significant differences. The same conditions were true generally for the organic matter, nitrogen, crude fibre and nitrogen free extract. The ether extract showed more variation than the other nutrients.

These results confirm those found previously that the digestibility of feeds determined with swine is not affected by the stage of growth.

Table 2 compares the various feeds on the basis of their contents of total digestible nutrients and digestible protein. These are expressed as percentages of the dry matter. Details concerning the chemical composition and the coefficients of digestibility of the individual nutrients will be found in Tables 3, 4, 6 and 7. The values for the vegetable protein concentrates were calculated from the mixed rations with barley. One fact should be noted in connection with the calculation of the total digestible nutrients in the soybean oil meal by the solvent process. The ether extract was only approximately one-half of one per cent and the coefficients of digestibility of this nutrient when calculated from the rations with barley gave negative results. This was taken into account in calculating the total digestible nutrients.

On the basis of the content of total digestible nutrients, it will be seen from Table 2 that the soybean oil meal produced by the expeller process and the rye were the highest of all feeds and, themselves, approximately

TABLE 1.—MEAN COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS OF RATIONS AS FED ARRANGED BY ANIMAL MEANS AND PERIOD MEANS (EACH MEAN BASED ON 8 VALUES, MISSING VALUE INCLUDED IN MEANS OF PERIOD 10 AND ANIMAL 10)

Designation	Mean coefficients of digestibility in % of Nutrients					
	Dry Matter	Organic Matter	Nitrogen	Ether Extract	Crude Fibre	N-Free Extract
Period 9	81.7	83.2	82.2	70.5	28.1	88.8
10	82.4	83.7	84.0	63.7	31.0	89.0
11	81.3	82.8	83.8	73.9	28.2	88.2
12	81.2	82.5	83.4	68.2	30.6	87.6
13	81.0	82.4	84.1	66.7	30.8	87.5
14	80.8	82.2	82.9	66.3	29.2	87.6
15	81.5	82.9	82.8	65.6	30.6	88.2
16	81.1	82.6	82.2	76.0	31.6	87.8
Total range	1.6	1.5	1.9	12.3	3.5	1.5
Necessary Difference*	0.9	0.8	1.4	5.6	3.4	0.8
Animal 9	81.6	83.0	84.6	69.3	29.6	88.2
10	81.2	82.7	82.0	65.5	24.9	88.4
11	81.3	82.8	83.7	66.2	29.2	88.0
12	81.0	82.4	82.6	68.0	31.6	87.6
13	81.2	82.5	83.6	71.0	31.5	87.8
14	82.5	83.8	84.3	71.7	32.2	88.9
15	81.2	82.6	82.5	67.8	33.5	87.9
16	80.9	82.5	82.1	71.1	27.8	88.0
Total range	1.6	1.4	2.6	6.2	8.6	1.3
Necessary Difference*	0.9	0.8	1.4	5.6	3.4	0.8

* At P of 0.05.

TABLE 2.—MEAN VALUES FOR THE TOTAL DIGESTIBLE NUTRIENTS AND THE DIGESTIBLE PROTEIN IN THE DRY MATTER OF THE INDIVIDUAL FEEDS

(Mean of 7 values for rye and 8 for the remainder)

Feedstuff	Digestible Nutrients in % of Dry Matter	
	Total	Protein*
Soybean Oil Meal		
(a) Expeller	88.8	38.4
(b) Solvent	81.7	40.6
Linseed Oil Meal		
(a) Carpenter	81.0	29.0
(b) Sherwin-Williams	81.3	26.9
Rye	88.7	11.8
Buckwheat	75.7	10.0
Screenings	79.3	13.7
Barley	83.9	10.8
Necessary Difference**	2.0	0.8

* Protein factors used (2) were, soybean oil meal—5.71, linseed oil meal—5.30, rye—5.83, buckwheat—5.83, screenings—6.25, and barley—5.83.
** At P of 0.05.

equal. They were higher than the barley. The two linseed oil meals and the soybean oil meal prepared by the solvent process had approximately equal contents of total digestible nutrients. They were slightly lower than the barley. Buckwheat had the lowest content. The screenings were less than the linseed oil meals but not quite significantly so.

TABLE 3.—MEAN CHEMICAL COMPOSITION OF FEED STUFFS

(Means of 8 values)

Feedstuff	Dry Matter %	Chemical Composition of Dry Matter in %				
		Ash	Protein*	Ether Extract	Crude Fibre	N-Free Extract
Soybean Oil Meal						
(*a*) Expeller	90.40	5.85	44.20	5.89	6.26	37.81
(*b*) Solvent	90.22	6.30	45.12	0.59	6.05	41.93
Linseed Oil Meal						
(*a*) Carpenter	91.08	5.07	35.25	6.48	9.11	44.10
(*b*) Sherwin-Williams	90.69	5.72	32.86	7.58	9.15	44.68
Rye	87.41	2.02	13.88	1.81	2.76	79.52
Screenings	88.69	2.66	16.77	4.76	7.31	68.49
Buckwheat	87.03	2.46	13.03	2.64	12.05	69.82
Barley	87.93	2.72	12.89	2.07	5.77	76.55

* Protein factors—see Table 2.

TABLE 4.—MEAN COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL FEEDS

(Mean of 7 values for rye and 8 for the remainder)

Feedstuff	Mean Coefficients of Digestibility of Nutrients in %					
	Dry Matter	Organic Matter	Nitrogen	Ether Extract	Crude Fibre	N-Free Extract
Soybean Oil Meal						
(*a*) Expeller	86.7	88.1	86.8	83.3	79.0	91.1
(*b*) Solvent	87.4	88.9	90.0	−161.8	77.3	91.9
Linseed Oil Meal						
(*a*) Carpenter	74.9	77.4	82.3	88.2	42.1	80.0
(*b*) Sherwin-Williams	74.2	76.7	81.9	91.0	37.7	79.2
Rye	88.9	89.8	84.7	39.9	41.2	93.3
Screenings	75.4	76.7	81.8	82.7	20.7	80.7
Buckwheat	74.1	75.1	76.9	82.4	6.8	85.9
Barley	83.1	84.6	83.5	66.8	24.0	89.7
Necessary Difference*	2.0	1.9	2.0	**	9.5	2.1

* At P of 0.05.

** Error too great to give a valid value.

As far as the digestible protein was concerned the two soybean oil meals had the highest content. This was due both to a higher digestibility and a higher absolute content of protein. The soybean oil meal by the solvent process was slightly higher than that by the expeller process. This was due mainly to a higher digestibility. Both linseed oil meals contained over 25% of digestible protein. One was slightly higher than the other. This was due to a difference in the absolute amount of protein and not to any difference in digestibility. Of the grains, screenings had the highest digestible protein content followed by the rye, barley and buckwheat in descending order.

TABLE 5.—DAILY FEED CONSUMPTION

(Weights in kilograms, ration legend given at foot of table)

Period No.	Feed consumed by animals numbered							
	9	10	11	12	13	14	15	16
9	B 1.00 SI 0 5	Bu 1.8	B 1.0 LI 0.5	B 1.8	B 1.2 LII 0.6	S 1.6	R 1.6	B 1.2 SII 0.6
10	B 1.35 LII 0.65		B 2.0	B 1.35 LI 0.65	B 1.35 SI 0.65	Bu 2.00	B 1.35 SII 0.65	S 2.00
11	Bu 2.20	B 1.35 LII 0.65	S 1.60	R 2.40	B 1.35 SII 0.65	B 2.20	B 1.60 SI 0.80	B 1.60 LI 0.80
12	B 1.30 SII 0.65	B 1.80	R 2.00	B 1.30 SI 0.65	Bu 1.8	B 1.30 LI 0.65	S 2.00	B 1.30 LII 0.65
13	B 1.50 LI 0.75	B 1.75 SII 0.85	B 1 75 LII 0.85	S 2.50	R 2.50	B 1.75 SI 0.85	Bu 2.50	B 2.00
14	B 2.60	B 1.80 SI 0.90	Bu 2.60	B 1 80 LII 0.90	S 2.60	B 1.80 SII 0.90	B 1.80 LI 0.90	R 2.60
15	R 2.20	S 2.00	B 1.80 SII 0 90	Bu 3.00	B 1.80 LI 0.90	B 1.80 LII 0.90	B 2.70	B 2.00 SI 1.00
16	S 2.20	B 1.80 LI 0.90	B 1.80 SI 0.90	B 1 80 SII 0.90	B 2.70	R 2.40	B 1.80 LII 0.90	Bu 2.80

Ration legend

SI —Soybean Oil Meal—Expeller process, Central Soya Co.
SII—Soybean Oil Meal—Solvent process, Archer Daniels, Montreal.
LI —Linseed Oil Cake Meal—Carpenter's, Hamilton.
LII—Linseed Oil Cake Meal—Sherwin-Williams Co., Montreal, Screw Press method.
Bu —Buckwheat—No. 1 C. E., Silverhull Variety.
R —Rye—No. 3 C. W. Feed Rye.
S —Screenings—Ground No. 2 Feed.
B —Barley—No. 1 Feed Western.

TABLE 6.—COEFFICIENTS OF DIGESTIBILITY OF RATIONS IN TABLE 5

Nutrient	Period No.	Coefficients of digestibility in % of following rations							
		Barley	Rye	Buck-wheat	Screen-ings	Mixed ration with barley			
						Linseed Oil Meal		Soybean Oil Meal	
						No. 1	No. 2	No. 1	No. 2
Dry Matter	9	82.9	89.3	73.6	78.2	81.0	79.6	86.5	82.8
	10	83.7	—	76.1	77.7	81.0	80.3	85.2	85.0
	11	83.7	89.0	74.4	75.0	78.9	80.2	84.2	85.2
	12	82.6	88.6	74.5	75.2	80.2	80.1	82.9	85.1
	13	82.6	88.6	73.7	74.0	80.9	79.9	84.4	84.0
	14	82.6	88.6	74.1	72.7	80.2	79.5	82.8	85.8
	15	82.6	88.8	74.2	76.3	80.0	81.7	84.4	84.1
	16	83.8	89.7	72.3	74.4	80.5	79.5	84.0	84.3
Organic Matter	9	84.4	90.0	74.7	79.6	82.8	81.4	87.8	84.6
	10	85.2	—	76.9	78.9	82.7	82.2	86.5	86.4
	11	85.2	89.8	75.3	76.5	81.1	82.2	85.6	86.5
	12	84.1	89.5	75.3	76.3	81.9	81.9	84.4	86.4
	13	84.2	89.4	74.6	75.2	82.7	81.9	85.8	85.5
	14	84.1	89.6	75.0	73.9	81.9	81.3	84.3	87.1
	15	84.3	89.6	75.2	77.3	81.8	83.5	86.0	85.7
	16	85.3	90.7	73.6	75.7	82.5	81.5	85.6	85.9
Nitrogen	9	80.9	81.9	75.1	81.2	82.8	83.5	89.0	83.3
	10	84.8	—	79.4	83.1	84.4	83.1	85.2	87.9
	11	84.4	85.5	76.7	83.9	81.0	82.4	85.1	91.0
	12	82.1	84.7	79.0	81.5	83.0	82.3	84.9	89.7
	13	85.0	84.5	78.2	82.1	86.0	83.6	86.7	86.8
	14	84.9	84.1	77.5	80.2	82.4	81.0	83.4	89.8
	15	81.9	86.0	76.2	80.7	81.7	84.0	85.1	86.7
	16	83.6	85.9	73.2	81.4	80.9	80.8	85.8	86.1
Ether Extract	9	65.9	40.0	82.0	84.4	80.7	81.9	84.3	44.7
	10	54.4	—	83.9	84.7	70.3	80.3	75.8	30.1
	11	68.9	51.7	81.8	85.5	84.6	89.7	73.7	55.0
	11	69.2	35.1	79.3	82.3	77.9	84.5	68.9	48.0
	13	65.8	39.9	82.6	84.0	81.4	76.7	75.2	28.0
	14	64.8	35.6	82.8	81.9	75.0	76.7	67.4	46.5
	15	72.0	23.4	81.9	67.9	80.6	83.4	84.1	31.1
	16	73.6	53.4	84.8	90.7	89.6	87.1	83.4	45.0
Crude Fibre	9	24.5	53.2	27.0	22.1	32.9	26.8	49.6	42.5
	10	26.4	—	10.5	23.9	30.3	28.7	49.0	43.4
	11	20.7	46.0	10.7	18.7	22.3	26.6	43.9	37.0
	12	20.2	41.2	17.7	21.8	38.1	29.0	39.6	37.5
	13	22.6	45.6	15.1	20.6	30.3	27.6	44.9	40.0
	14	24.9	28.7	5.1	15.2	36.6	33.2	42.0	47.8
	15	22.2	37.2	9.7	25.4	30.4	37.0	40.7	42.5
	16	30.1	36.2	12.7	17.6	35.5	31.9	39.4	49.2
Nitrogen-free extract	9	89.9	94.1	86.7	84.1	88.2	86.9	91.1	89.7
	10	90.1	—	87.4	82.8	88.1	87.7	90.7	90.6
	11	90.5	92.9	87.4	79.9	87.5	87.6	90.1	90.0
	12	89.5	93.2	85.4	79.8	86.3	87.0	89.0	90.2
	13	89.0	92.9	85.1	78.6	87.4	87.1	89.6	90.0
	14	89.0	93.1	85.8	78.6	87.1	87.0	89.2	90.7
	15	89.4	93.0	85.1	81.8	87.6	88.1	90.4	90.2
	16	90.3	94.2	84.3	79.7	87.6	86.9	89.7	89.9

TABLE 7.—COEFFICIENTS OF DIGESTIBILITY OF THE VEGETABLE PROTEIN CONCENTRATES CALCULATED FROM MIXED RATIONS WITH BARLEY

(Coefficients in %)

Feed	Period	Coefficients of Digestibility of Nutrients					
		Dry Matter	Organic Matter	Nitrogen	Ether Extract	Crude Fibre	N-Free Extract
Soybean Oil Meal I	9	93.1	94.4	91.8	97.7	94.2	96.6
	10	89.4	90.4	86.2	81.8	94.6	95.0
	11	86.4	87.6	86.0	78.5	78.3	91.6
	12	82.6	84.0	85.5	70.3	67.6	86.0
	13	87.1	88.4	88.5	80.8	83.1	89.2
	14	82.3	83.7	83.4	67.8	76.2	87.3
	15	86.9	88.9	85.9	95.3	69.6	92.9
	16	85.8	87.6	87.0	94.3	68.6	89.9
Soybean Oil Meal II	9	82.2	84.6	83.2	−37.5	77.6	89.9
	10	88.8	90.1	90.4	−400.0	80.6	94.0
	11	89.5	90.4	95.2	−55.0	60.7	91.2
	12	88.9	90.2	93.0	−114.3	63.2	92.0
	13	85.9	87.4	88.8	−248.3	69.5	91.3
	14	91.2	92.3	93.2	−106.7	93.8	94.4
	15	86.1	88.0	88.4	−223.3	76.9	91.8
	16	86.8	88.4	87.5	−109.7	96.3	90.7
Linseed Oil Meal I	9	76.9	79.2	82.6	90.8	43.9	83.3
	10	76.7	78.9	85.0	72.5	38.3	82.7
	11	70.7	74.2	79.5	96.1	20.2	80.0
	12	74.5	76.6	82.5	85.4	55.0	75.1
	13	76.7	79.1	87.6	89.9	37.8	79.8
	14	74.5	76.6	81.7	79.6	53.7	78.3
	15	73.9	76.3	80.6	88.7	37.9	80.6
	16	75.6	78.2	79.2	102.9	49.7	80.3
Linseed Oil Meal II	9	72.7	75.0	83.5	90.7	30.2	77.3
	10	74.7	77.2	82.9	86.7	34.4	81.0
	11	74.4	77.4	81.6	102.5	29.8	80.1
	12	74.2	76.5	81.2	94.8	35.1	78.1
	13	73.5	76.2	83.7	82.5	32.0	78.3
	14	72.5	74.7	79.2	81.6	45.0	77.9
	15	79.1	81.3	84.3	91.8	52.6	82.9
	16	72.5	75.3	78.8	97.8	42.2	77.9

SUMMARY

Using an 8 × 8 randomized Latin square, coefficients of digestibility were determined with growing swine for the following feeds: soybean oil meal (expeller process), soybean oil meal (solvent process), linseed oil cake meal (two lots), buckwheat, rye, screenings and barley.

During the 26 weeks of the experiment, the digestibilities of the feeds were not affected by the increasing weights of the animals.

There were no marked differences between the various animals in their ability to digest the feeds.

Values for the total digestible nutrients and digestible protein of the 8 feeds were listed.

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MALTING QUALITY OF CANADIAN BARLEYS: V. SUMMARY OF SEVEN YEARS TESTS ON MONTCALM, A NEW SMOOTH AWNED VARIETY[1]

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The object of this series of papers is to record information on the malting quality of varieties of barley grown in Canada. The Canadian barley grading system takes into account the relative malting quality of varieties and excludes poor varieties from the higher grades, thus information on new varieties is of interest and value to users of Canadian barley. Only a few of the varieties discussed in previous papers of this series (3, 4, 9, 10) enter commercial channels, and the information has been of more value to plant breeders than to the barley trades. The former required information on the relative merits for malting purposes of the more common varieties that were being used in breeding programmes. This is the first in a series of papers dealing with a variety which is expected to make a significant contribution to top grades of barley. This variety, Montcalm, is a smooth awned variety with a blue aleurone layer that was produced by Professor Emile A. Lods, Macdonald College, Quebec. Its origin is (Michigan 31604 × Common Six-row) × Mandscheuri, and the original cross was made in 1922. Malting tests have been made on Montcalm in comparison with O.A.C. 21 each year since 1939, and a summary of the results is now presented. The malting quality of Montcalm is satisfactory and the Board of Grain Commissioners have ruled that the variety is eligible for the highest grades of six-row barley.

The data represent comparisons of Montcalm and O.A.C. 21 over a period of 7 years, during which 77 pairs of samples were tested. Eight stations in Eastern Canada and 18 stations in Western Canada submitted samples during the 7 years of testing, so that a considerable range of environment is represented in the study. It is thus possible to obtain a fairly comprehensive picture of the performance of Montcalm in comparison with that of O.A.C. 21. The terms used in discussing malting quality have been reviewed and explained in previous papers (3, 4, 9, 10) and need not be discussed further in this.

MATERIALS AND METHODS

The barley samples were collected from various agronomic trials conducted during the years 1939-1945. The number of samples tested in each year, and the stations represented, are given in Table 1. The agronomic trials were conducted in the same manner as in previous years (3, 4, 9) and the grain from replicate plots was bulked to provide the amount of material required for malting tests.

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TABLE 1.—NUMBER OF SAMPLES TESTED IN EACH YEAR, AND LOCATION AT WHICH GROWN

Year	No. of samples	No. of stations	Stations
1939	3	3	Ste. Anne de la Pocatiere, Macdonald College, Lennoxville.
1940	3	3	Ste. Anne de la Pocatiere, Macdonald College, Lennoxville.
1941	8	8	Ste. Anne de la Pocatiere, Macdonald College, Lennoxville, Ottawa, Almonte, Kemptville, Manotick, Guelph.
1942	5	5	Ste. Anne de la Pocatiere, Macdonald College, Lennoxville, Ottawa, Guelph.
1943	8	8	Ste. Anne de la Pocatiere, Macdonald College, Lennoxville, Guelph, Winnipeg, Brandon, Edmonton, Fallis.
1944	23	17	Ste. Anne de la Pocatiere, Macdonald College, Lennoxville, Guelph, Brandon, Goodlands, Melita, Swan River, Tisdale, Indian Head, Edmonton, Fallis, Athabaska, Bon Accord, Warburg, Sundre, Lacombe.
1945	27	17	Ste. Anne de la Pocatiere, Macdonald College, Lennoxville, Winnipeg, Brandon, Goodlands, Melita, Swan River, Kemptville, Tisdale, Indian Head, Melfort, Edmonton, Fallis, Lacombe, Bowden, Cremona.

TABLE 2.—COMPARISON OF BARLEY, MALTING AND MALT PROPERTIES OF O.A.C. 21 AND MONTCALM, AS MEANS OVER 7 CROP YEARS

Property	O.A.C 21	Montcalm
BARLEY		
Bushel weight, lb.	50.4	50.7
Plump barley, %	80.2	86.5
1000 kernel wt., gm.	33.2	33.8
Nitrogen, %	2.29	2.16
MALTING		
Hours steep	56.0	57.0
Malting loss, %	9.0	9.0
MALT		
Extract, %	75.4	76.4
Saccharifying activity, ° L.	122.0	129.0
Wort nitrogen, %	1.21	1.12
Index of nitrogen modification, %	39.7	39.8
Number of samples	77	77

Malting

The samples were prepared for malting and malted by the standard methods (9) and with equipment that has been described previously (2, 5, 8).

Analysis

The commonly measured properties of barleys and malts were determined by the standard procedures previously described (9). Additional barley, malt, and wort properties were determined by the methods described in another series of papers (1, 6, 7, 11, 13, 14). Alpha amylase activity was determined by the methods of other workers (12, 15).

TABLE 3.—COMPARATIVE BARLEY, MALTING AND MALT PROPERTIES OF MONTCALM EXPRESSED AS DIFFERENCES FROM CORRESPONDING MEAN VALUE FOR O.A.C. 21 IN EACH YEAR

Year	No. of samples	Barley				Malting		Malt			
		Bu. wt.	Heavy grade	1000 K. wt.	Nitrogen	Hrs. steep	Malting loss	Extract	Saccharifying activity	Wort nitrogen	Index of nitrogen modification
		lb.	%	g.	%		%	%	°L.	%	%
1939	3	—	2 8	0 9	−0.04	0	−0.4	1.0	3	−0.07	−1.4
1940	3	—	6.6	0.2	−0.13	−2	0.3	1.2	21	−0.15	−2.3
1941	8	—	15 3	1 8	−0 20	3	0 3	1 7	3	−0.07	2.3
1942	5	—	5.1	0 8	−0.10	3	0.1	0.9	10	−0.08	−0.3
1943	8	—	4.4	−0.1	−0.18	0	0.1	1.7	1	−0.11	0.6
1944	23	0.2	3.9	0 3	−0.12	0	0.2	0.8	10	−0.07	0.2
1945	27	0.4	7.0	0.9	−0.11	3	−0.2	0 8	5	−0 08	−0.5

RESULTS AND DISCUSSION

The data from the determinations made on the 77 pairs of samples are so numerous that it is necessary to present them only in summary form. The direct comparisons of the mean values of O.A.C. 21 and Montcalm for the commonly measured properties are given in Table 2.

These data show that Montcalm is slightly higher than O.A.C. 21 in bushel weight, definitely higher in yield of heavy grade barley suitable for malting, slightly higher in kernel weight, and definitely lower than the standard variety in barley nitrogen content. These features, all advantageous, show that Montcalm therefore possesses satisfactory barley properties. The two varieties are practically identical in properties measured during malting, viz., length of steep required to reach 44% moisture content, and amount of loss due to respiration and roots. Similarity in these properties, among varieties eligible for the same grades, is essential for successful malting as farmers' deliveries of the same grade are mixed at country elevators and carlots of the same grade are mixed at terminal elevators. If two varieties of dissimilar characteristics are mixed, considerable difficulties are encountered in malting as one variety may be understeeped and the other may be oversteeped; there would also be further trouble in the floor on account of irregular growth. The similarity in the steep and growth rates of Montcalm to those of O.A.C. 21 should therefore permit satisfactory malting of the mixture of these varieties that will occur.

The actual malt properties of Montcalm are of principal interest. The data show that Montcalm is 1% higher than O.A.C. 21 in malt extract and slightly higher in saccharifying activity. The value for wort nitrogen content of Montcalm is somewhat lower than that for O.A.C. 21, but the difference is accounted for by the difference in barley nitrogen. This is shown by the data for index of nitrogen modification which represents the proportion of original nitrogen content that is made soluble during malting and mashing. The malt qualities of Montcalm are thus fully equal to those of O.A.C. 21, in fact, Montcalm can be considered superior to O.A.C. 21. A point of interest is that, despite the fact that Montcalm is lower than O.A.C. 21 in nitrogen content, it is higher in saccharifying activity.

Usually, though more generally within a variety, low nitrogen content is accompanied by low enzymatic activity. The data thus show that Montcalm represents a marked advance in quality from the status described a few years ago (3, 10) when the smooth awned varieties as a class were characterized by low malt extract content and low enzymatic activity.

It is also important to determine the consistency of Montcalm in relation to O.A.C. 21 over the test period. Data on this point are given in Table 3. In this table the mean values, for each year, for Montcalm are expressed as differences from the mean values for O.A.C. 21. A negative sign indicates that the value for Montcalm is lower than that for O.A.C. 21. while absence of sign indicates that the Montcalm value is higher. In order that the absolute values for Montcalm may be ascertained, the mean values for each year for O.A.C. 21 are given in Table 4.

The data given in Table 3 show that Montcalm is very consistent in its properties when the values are expressed as differences from O.A.C. 21. O.A.C. 21 is considered to be a very stable variety in its reaction to change in environment (3), and Montcalm is in the same class as the standard. The detailed data for the 77 individual pairs of samples, which are not given in this paper, show that this consistency is evident throughout the entire series of samples.

The properties discussed up to this point are those that are studied during routine malting tests and are measured on the barley, during malting, and on the malts. On the basis of these measurements, primary separation of barley varieties into "not promising" and "promising" classes are made. Such classifications were made in the first four papers in this series (3, 4, 9, 10) and they are adequate for decisions on inferior varieties. However, even when a variety compares favourably with O.A.C. 21 in the properties commonly measured, there is no real certainty that the variety will find acceptance in commercial malting and brewing. In order that varietal recommendations can be made with more certainty, additional properties that have some bearing on malting quality and on commercial utilization are studied.

The values for O.A.C. 21, and Montcalm, for a number of additional barley, malt and wort properties, are listed in Table 5. The significance of these properties has been reviewed in other papers (1, 6, 7, 11, 13, 14).

TABLE 4.—BARLEY, MALTING AND MALT PROPERTIES OF O.A.C. 21, MEAN VALUES FOR EACH OF 7 YEARS

Year	No. of samples	Barley				Malting		Malt			
		Bu. wt.	Heavy grade	1000 K. wt.	Nitrogen	Hrs. steep	Malting loss	Extract	Saccharifying activity	Wort nitrogen	Index of nitrogen modification
		lb.	%	g.	%		%	%	°L.	%	%
1939	3	—	88.2	33.5	2.14	60	8 4	75 0	121	1 16	41.1
1940	3		77 2	33 1	2 09	59	10 0	75 4	113	1 19	42 9
1941	8	—	67 3	30.6	2 39	52	12 3	74 8	156	1 30	40 7
1942	5	—	81.1	34 2	2 06	58	9 3	76 6	113	1 19	44.2
1943	8	—	85 0	34 2	2 23	60	8 3	75 6	119	1 21	41 0
1944	23	50 6	82.0	34 0	2 24	60	8 7	75 6	112	1 18	39 8
1945	27	50.2	80.2	32 7	2 41	50	8 4	75 1	124	1 21	37 8

Many of the determinations were made on samples representing two crops, 1941 and 1945, so that again there is information on the stability of Montcalm in relation to O.A.C. 21. The results in Table 5 show that, aside from differences in total and salt-soluble barley nitrogen and in wort nitrogen, the two varieties are essentially similar in properties. Actually, practically all the comparisons are in favour of Montcalm. The turbidity data show that Montcalm wort is slightly more turbid than O.A.C. 21 wort, when examined immediately after filtration, but the differences are small and actually not discernible without the use of special instruments. After standing, the turbidity of Montcalm wort is lower than O.A.C. 21 wort, which represents greater wort stability.

TABLE 5.—COMPARISON OF O.A.C. 21 AND MONTCALM IN A NUMBER OF ADDITIONAL BARLEY AND MALT PROPERTIES

Property	1941 Crop, 8 samples		1945 Crop, 10 samples	
	O.A.C. 21	Montcalm	O.A.C. 21	Montcalm
BARLEY				
Total nitrogen, %	2.39	2.18	2.40	2.28
Salt soluble nitrogen, %	0.63	0.59	—	—
Saccharifying activity, ° L.	219	217	221	230
Extract, %	74.9	76.8	75.2	76 8
MALT				
Saccharifying activity, ° L.	156	159	127	132
Autolytic saccharifying activity, mg. maltose	715	808	—	—
Alpha amylase activity	55[1]	56[1]	97[2]	100[2]
Proteolytic activity, mg./100 gm.	221	239	—	—
WORT				
Nitrogen, %	1.30	1.23	1.21	1 12
Attenuation, %	80.1	82.7	85.9	89.0
Viscosity	1.444	1 417	1 492	1.467
Initial turbidity, %	17	26	26	29
Turbidity after 24 hours, %	148	124	211	197

[1] Nebraska units. [2] Wisconsin units, mg. malto-e.

The summation of the properties studied, therefore, indicates that Montcalm is of the same type as O.A.C. 21 in malting quality. Moreover, Montcalm is superior to O.A.C. 21 in malt extract and saccharifying activity. These two properties are important in industrial use and present indications are that Montcalm will be accepted with favour by commercial maltsters. Several companies in Canada and the United States have malted small samples of Montcalm and regard the results with satisfaction. No large lots of Montcalm have been malted and brewed as yet, but from pilot plant tests made in an industrial laboratory it was concluded that Montcalm and O.A.C. 21 produce similar results in the brewhouse.

SUMMARY

The results of malting tests made on 77 paired samples of O.A.C. 21 and Montcalm over a period of 7 crop years are summarized. Montcalm compares very favourably with O.A.C. 21 in all properties measured. It yields a somewhat higher percentage of heavy grade barley suitable for malting than does O.A.C. 21, and its kernels are slightly larger. The

barley nitrogen content of Montcalm is lower than that of O.A.C. 21, yet Montcalm appears to be adequately supplied with enzymes. As a result, Montcalm is about 1% higher than O.A.C. 21 in malt extract. The two varieties are identical in steep requirements and growth rate, and no difficulty is anticipated in malting mixtures of the varieties. A number of additional barley, malt and wort properties were examined, and Montcalm compares favourably with O.A.C. 21 in these. It is concluded that Montcalm is fully equal to O.A.C. 21 in malting quality.

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THE EFFECT OF PHOSPHATIC FERTILIZERS ON SUMMER-FALLOW WHEAT CROPS IN CERTAIN AREAS OF SASKATCHEWAN[1]

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The use of phosphatic fertilizers is becoming a standard practice on many farms in Saskatchewan. This development is a relatively recent one, there being little commercial fertilizer used previous to the year 1927 when high analysis fertilizers were first introduced, and the principle of drilling the fertilizer with the seed was accepted. From 1927 until recent years the use of phosphates has tended to increase but slowly, partly because of the discouraging dry years of the thirties. It is only the past few years that there has been any marked increase in tonnage used, although results obtained in a series of trials conducted co-operatively between Dominion and Provincial Depts. of Agriculture, Universities and commercial firms during 1928-1930 (6) were quite encouraging to the use of phosphates in the Prairie Provinces.

It is not unusual to find comparatively fertile soils such as are common to this area responding to phosphates after some 30 to 40 years of cultivation. Bear (1) states that "it is a matter of common experience that soils become deficient in available phosphorus early in their agricultural history," and Russell (9) mentions phosphate deficiency as being common to many parts of the world. Truog (12) states that the minimum amount of available phosphorus sufficient for a crop depends upon the kind of crop, the soil and the climate. All three factors mentioned by Truog are well recognized, but it is doubtful if the factor of climate at least has generally been given sufficient emphasis. The effect of phosphates in hastening ripening is of immense importance in areas where growing seasons are short. Earliness may have other important effects such as avoidance of rust damage, escaping of insect attack, and in some seasons avoiding the full impact of a period of drought. However, if drought occurs too early in growth, the fertilized fields commonly suffer the effects of hot dry weather as do the unfertilized crops, but the yield of the former is not necessarily reduced to that of the latter (9). The beneficial value of phosphates in combatting the effect of root rots has been reported by Vanterpool (14) and Russell and Sallans (10). Godel (3) reports that treated crops are enabled to compete more successfully with weeds.

The total phosphorus in Saskatchewan soils (13) ranges from 0.03 to 0.10% except in rare cases, and by far the larger number of analyses show results between 0.05 and 0.08%. Therefore, the percentage of elemental phosphorus in these soils is not unusually high (11) and such amounts of phosphorus were undoubtedly orginally present in many soils which, with

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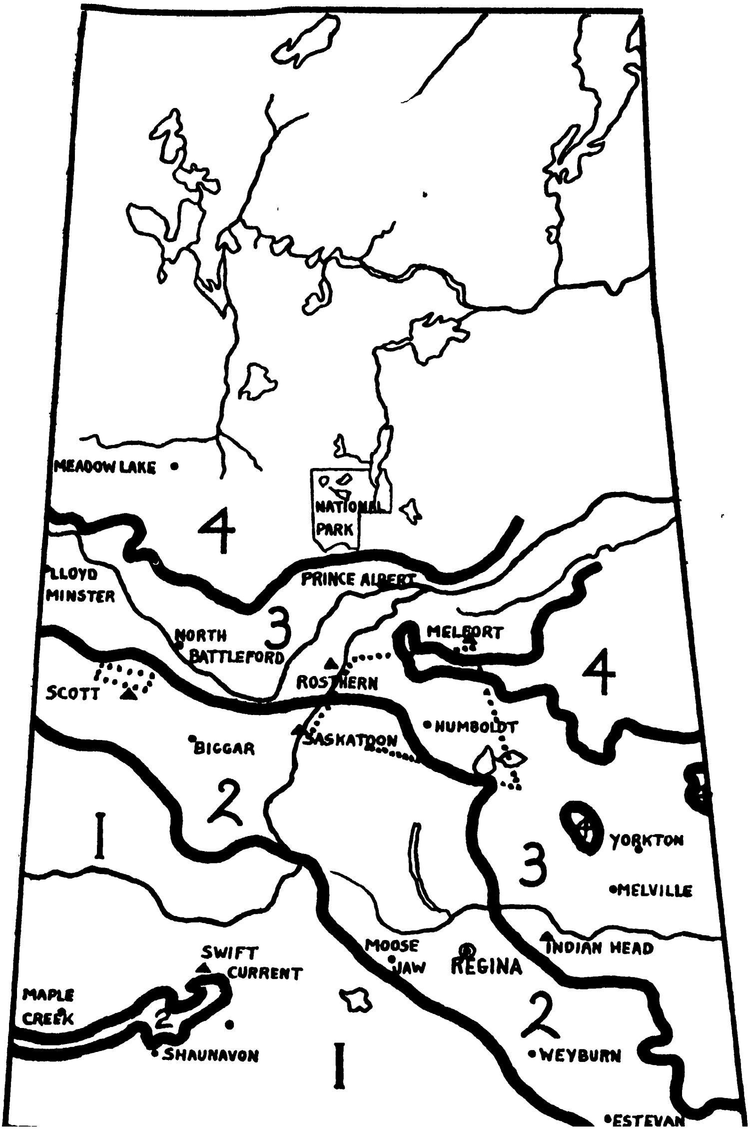

FIGURE 1. Sketch Map Showing Soil Zones of Saskatchewan and General Location of Test Plots.

LEGEND

1. Brown Soils—short grass prairie and western section of mixed prairie.
2. Dark Brown Soils—mixed prairie grass section.
3. Black Soils—"Park Belt" or "Aspen Grove" section.
4. Grey (podzolic) Soils—forested section.

. . . . Boundary of area within which test plots were located.

* Adapted from Sask. Soil Survey Report No. 12 (4).

only a slightly longer cropping history, are now giving good responses to fertilization. The "availability" of the phosphorus is much more variable (5) than is the total phosphorus. In general the leached soils such as podzols and solods have the lowest availability (13), and heavy soils commonly are higher in "available" phosphorus than are sandy ones. The availability is lowest in soils with well developed A_2 horizons, and is often very low in such horizons.

The variability of climatic conditions across Saskatchewan is a factor not readily appreciated. The factor of rainfall has been overstressed and the importance of temperature, humidity and wind velocity has not been given sufficient attention. The average annual rainfall varies between 11 in. and 19 in. but Swift Current with an average rainfall of 15.18 in. is in the brown soils zone of the Prairie-plains while Prince Albert with only 15.87 in. rainfall is on the border of the podzolic soil zone, and the mixed wood forest. Climatic conditions are entirely different at these places, and so therefore is the general character of soil and vegetation. Plainly, these differences are not due to rainfall alone.

Southwestern Saskatchewan is the most arid area of the province, the aridity decreasing towards the north and east. At the same time average temperatures are much lower towards the north, and growing seasons shorter, although this trend is less marked towards the east. Variability of seasons is also greatest in the warmer and drier southwest and lessens towards the north and east. Table 1 gives average annual temperatures and average precipitation for Swift Current in the brown soil zone (see Figure 1), Saskatoon in the dark brown, Melfort in the black, and Prince Albert on the border of the gray wooded zone. A study of these data clearly indicate the relative importance of temperature as compared to rainfall in considering the climate of the various areas within this province. These variations in temperature and precipitation give rise to well defined climatic, soil, and vegetational zones within the province (Figure 1) and are of significance in relation to cropping practices, and in the results reported herein relative to the use of phosphates.

SCOPE AND PLAN OF EXPERIMENTS

The purpose of these experiments was to test in the field three common kinds of phosphatic fertilizers at several rates, so that differential responses due to rates and kind could be measured. In addition, the matter of variability of response on different soils, and in different seasons was kept in mind throughout the investigation. The results reported herein were obtained during the seasons of 1939 to 1943.

Since it was deemed desirable that the data should reflect as closely as possible results which the farmer might obtain, the following plan was adopted. Each treatment was seeded a drill width the length of the field selected. The farmer's own drill and attachment were used, or an attachment was supplied in cases where the farmer did not own one. A check strip was left adjacent to each treated strip. When harvesting, 10 individual square yard samples were taken from each strip. Each sample was threshed and weighed separately. Students' pairing method was used in calculating the statistical significance of results.

Three kinds of fertilizers were used in the trials, each applied at 4 rates, as follows:—

Fertilizer	(Lb. per acre)			
	Rate 1	Rate 2	Rate 3	Rate 4
11–48–0	15	25	35	50
0–43–0[1]	17	28	40	56
2–20–0[2]	15	25	35	75

[1] In last year of experiments 0–43 0 was no longer available, so 0–38 0 was used at 19, 32, 44 and 63 lb. per acre.

[2] A 2–19 0 fertilizer was used for the first 2 years of trials.

It may be pointed out that exact rates could not be obtained under the conditions of the tests. However, variations were kept as small as practicable by checking the amount passing through the attachment and adjusting to as near the desired rate as possible.

The triple super-phosphate was applied at rates giving equivalent amounts of P_2O_5 to comparable rates of 11–48–0.

The first 3 rates of 2–20–0 were applied at the same rates as the 11–48–0 to give a direct comparison between lower analysis and higher analysis fertilizers, and to furnish an opportunity to study the effect of still lower applications of P_2O_5. The fourth rate of 2–20–0 (75 lb. per acre) was intended to apply equal amounts of P_2O_5 to that applied in the third rate 40 lb. per acre, but some difficulty was encountered in applying the material with the attachments used. The 75 lb. rate of 2 20 0 gives an application of 15 lb. of P_2O_5 and 1.5 lb. of nitrogen compared to the 40 lb. rate of 0–43–0 which gives 17 lb. of P_2O_5.

All trials were on wheat seeded on summerfallowed land, since experience indicated that fertilization was ineffective on second crops. This matter deserves further investigation since there is little doubt that favourable responses are obtained on other than summerfallow land in districts where more favourable moisture conditions obtain. No attempt was made to check residual effects of the fertilizer. Results from the Dominion Experimental Station at Swift Current in the drier brown soil zone (Figure 1) are not encouraging to the use of fertilizer even on summerfallow crops (7). These trials were therefore confined to the area indicated in Figure 1 touching on three major soil zones, namely, the dark brown, black and gray wooded (podzolic) soils. The largest number of experiments were on black soils with slightly fewer on the dark brown, only 4 experiments were on gray wooded soils. Three trials were situated in the western section of the dark brown soil zone near the towns of Wilkie and Unity.

Types of soils on which trials were placed included those most prominent in the area. In the dark brown soil zone the trials were on medium textured soils of the Weyburn and Elstow associations with the exception of two on the lighter textured Asquith and three on Elstow clay out of a total of 23 sets of plots.

In the black soil zone the tests were mainly on medium textured soils. However, these soils were of two distinct types; namely, high lime and normal types. The high lime types included Yorkton, Canora and Cudworth Associations on which there were 22 trials. The non-limy were the Naicam, Oxbow and Melfort on which there were 26 trials. The high lime group are rendzina-like soils containing lime throughout the profile or at least into the lower A horizon. The non-limy soils have no free lime in the A or B_1 horizons and might be considered normal regional soils. There is, of course, a lime layer present in the lower B horizon of the latter soils. The aforementioned soils are described in Soil Survey Report No. 12, University of Saskatchewan (4).

Only four trials were situated on podzolized soils, the soils represented being the Whitewood and Waitville loams.

NATURE OF SEASONS DURING WHICH TRIALS WERE CARRIED ON

The weather through three of the seasons of the tests was quite typical for the area. These were 1939, 1940 and 1942. The seasons of 1941 and 1943 were quite dry in the area of the tests, but the season of 1941 was one of higher than average temperatures as well as of low rainfall. This fact will be referred to later in discussing the results of the tests. For comparison, the average temperatures and total precipitation for the month of June and July in the seasons of these tests are given in Table 2.

Table 3 shows the average increase obtained for each fertilizer at the various rates in the seasons 1939-1943. The percentage increase over check plots is also shown and the number of plots of each rate which gave highly significant, significant, or not significant increases. Detailed results of individual tests have already been published in mimeograph form for each season except for the last year of the trials (8).

TABLE 1.—AVERAGE ANNUAL TEMPERATURE AND ANNUAL PRECIPITATION AT SWIFT CURRENT, SASKATOON, MELFORT AND PRINCE ALBERT

—	Soil zone	Average temperature	Average precipitation
Swift Current	Brown	38.10°	15.18 in.
Saskatoon	Dark brown	33.30°	14.80 in.
Melfort	Black (deep)	31.10°	15.25 in.
Prince Albert	Border of gray wooded	31.60°	15.87 in.

TABLE 2.—AVERAGE TEMPERATURE AND PRECIPITATION FOR JUNE AND JULY IN SEASONS 1939-1943, WITHIN AREA OF TESTS (DATA FROM 7 DOMINION METEOROLOGICAL STATIONS WITHIN AREA)

—	June		July	
	Average temperature	Precipitation	Average temperature	Precipitation
1939	53.6°	6.1 in.	65.6°	2.1 in.
1940	56.6°	3.4 in.	63.2°	2.5 in.
1941	62.3°	2.0 in.	68.1°	1.7 in.
1942	57.6°	5.6 in.	61.5°	2.6 in.
1943	54.6°	1.3 in.	65.7°	1.8 in.

TABLE 3.—AVERAGE INCREASES FOR THREE FERTILIZERS AT 4 RATES FOR 1939 TO 1943

—	Fertilizer	Rate per acre	Total number of plots	Average bu. increase per acre	% increase	Number of results: Highly significant	Significant	Not significant
1939	11–48–0	15#	19	8.6	29.5	14	3	2
		25	20	9.9	34.0	13	1	6
		35	21	11.2	38 5	14	4	3
		50	20	13.0	44.0	16	3	1
	0–43–0	17	20	5.9	22.0	10	1	9
		28	21	7 2	25.0	13	3	5
		40	21	9.0	31.0	12	6	3
		56	21	10 3	35 5	16	1	4
	2–19–0	15	20	2.4	8.3	0	3	17
		25	21	4.6	15 8	6	4	11
		35	21	4.5	15.5	5	6	10
		75	20	7 0	24 0	11	3	6
1940	11–48–0	15	14	6 5	24.5	7	0	7
		25	14	10.2	38.5	12	1	1
		35	14	11.5	42 5	10	2	2
		50	14	12.2	46 0	10	3	1
	0–43–0	17	14	5.3	20 0	5	2	7
		28	14	8.6	32.5	8	4	2
		40	14	10 7	40 0	11	2	1
		56	14	12.7	48 0	13	1	0
	2–19–0	15	14	2 4	9 0	1	2	11
		25	14	3.7	14 0	5	1	8
		35	14	4 5	17 0	3	4	7
		75	14	6 6	25.0	8	2	4
1941	11–48–0	15	14	3 5	19 5	6	3	5
		25	14	2 8	17 0	3	5	6
		35	14	2.0	12.0	3	3	8
		50	15	4 5	25.0	7	3	5
	0–43–0	17	15	2 5	14 0	5	3	7
		28	15	2.4	13 5	2	1	12
		40	15	3.9	22 0	4	3	8
		56	15	3.7	21 0	5	5	5
	2–20–0	15	15	0.5	2.7	[illegible]	2	11
		25	15	0.8	4.5	0	1	14
		35	15	0.9	5 0	0	1	14
		75	15	1.2	6.8	1	1	13
1942	11–48–0	15	14	9.6	36 0	11	2	1
		25	15	11.3	42.5	13	1	1
		35	15	12.1	45 5	13	1	1
		50	15	13.4	50.0	13	1	1
	0–43–0	17#	15	5.4	20.0	8	3	4
		28	15	7.0	26.5	9	3	3
		40	15	9.8	37.0	12	2	1
		56	15	12 6	47.5	15	0	0
	2–20–0	15	15	3.3	12.5	4	2	9
		25	15	4.3	16.0	5	4	6
		35	15	5.2	19.5	5	4	6
		75	15	7.6	28.5	10	3	2

TABLE 3.—AVERAGE INCREASES FOR THREE FERTILIZERS AT 4 RATES FOR 1939 TO 1943—*Continued*

—	Fertilizer	Rate per acre	Total number of plots	Average bu. increase per acre	% increase	Number of results:		
						Highly significant	Signi-ficant	Not significant
1943	11–48–0	15	10	4.6	27.0	6	0	4
		25	10	5.4	31.5	7	1	2
		35	10	5.6	33.0	6	1	3
		50	10	8.2	48.0	9	0	1
	0–38–0	19	10	3.7	21.5	2	2	6
		32	10	5.0	29.0	5	1	4
		44	10	5.6	33.0	8	0	2
		63	10	7.1	42.0	9	0	1
	2–20–0	15	10	0.6	3.5	0	0	10
		25	10	1.8	10.5	2	1	7
		35	10	1.5	9.0	1	1	8
		75	10	2.7	16.0	3	1	6

DISCUSSION OF RESULTS

The averaged results reported herein indicate a remarkably good response to small applications of fertilizer on the summerfallow wheat crop. As might be expected, considerable variation in response as between individual farms was recorded. If comparisons were made between seasons, this variation was considerably enhanced. For instance, in 1939 the smallest increase was 5.6 bu. and the greatest 21.4 bu. for the 50# rate of 11–48–0 fertilizer. However, the smallest increase in the 5 years was recorded in 1941 (1.4 bu.) and the greatest in 1940 (25.0 bu.). As mentioned elsewhere, the dry season of 1941 gave relatively poor results. It might also be noted that out of 75 trials, there were only 9 cases in which the 50# rate of 11–48–0 failed to give significant increases and 5 of those were in 1941 (Table 3). The usual effects of phosphates were observed in respect to earlier maturity, better tillering and in more effective competition with weeds. The effect on maturity was somewhat erratic since in some fields the earliness would be pronounced (up to 10 days) while in others the difference would be slight, although the increase obtained might be quite as good. A similar situation seemed to prevail with regard to tillering. However, this and the matter of weed suppression was only incidentally observed throughout the period of these trials.

The best fertilizer on the average was 11–48–0 ammonium phosphate (Table 4). Triple superphosphate gave smaller increases at the same rates of P_2O_5, this difference being somewhat more pronounced at the lower rates. The 2–20–0 showed the least effect but on the average the results were about proportional to the amount of P_2O_5 applied. At the lower rates of application, few plots showed significant increases in the case of the latter fertilizer, a result which might have been expected, considering the small amount of nutrients applied at these rates.

On the average, the greatest increases in yield were obtained from the highest rates of application. However, the commonly observed effect that the first increment of a nutrient will produce relatively greater increases

than subsequent ones, is evident in these data. The maximum possible increase obtainable was not established with the rates used in these trials.

Low rates are considered the safest and best in this relatively dry region because of the fear that higher rates would produce a growth too luxuriant for the limited moisture supply to sustain. The presently recommended rates of 11–48–0 are from 20 to 40 lb. per acre. It appears from these data that the higher rates would be advantageous especially in areas where moisture supplies are generally satisfactory, and on heavier soils with better moisture holding capacity. It should also be pointed out that higher rates are ultimately likely to become necessary as phosphorus becomes more deficient in the soil. Twenty lb. of 11–48–0 will hardly supply phosphorus for one good crop after summerfallowing while a common practice in the area of these tests is to grow at least two grain crops after fallowing, of which only the summerfallow crop is fertilized. At the lower rates, depletion of phosphorus will therefore continue, and the balance will have to be met eventually by using higher rates of application.

Table 4 illustrates the lessening advantage which 11–48–0 showed over triple superphosphate at the higher rates. At the lowest rate (15# of 11–48–0, 17# of 0–43–0) there was an advantage in yield of 2.1 bu. in favour of the 11–48–0. However, at the highest rate the advantage was only 1.1 bu. for the 11–48–0. Since the same amount of P_2O_5 was applied at each comparative rate of the two fertilizers, part of the advantage obtained from the 11–48–0 may be attributed to the nitrogen in the latter fertilizer. However, there is also the possibility that the nature of the carrier compound might have an influence on the availability of phosphorus to the plant. The matter of response to nitrogen is one being given further study in connection with the use of fertilizer in this area.

As shown in Table 3, the years 1939, 1940 and 1942 gave increases which were quite similar both in the bu. increase and the % increase over checks. The season of 1943 was rather dry but while the bushels per acre

TABLE 4.—AVERAGE INCREASE FOR ALL TRIALS AND COST OF FERTILIZER PER ACRE

Fertilizer	Approximate rate lb. per acre	Approximate cost per acre	Average increase bu. per acre, 1939-1943
		$	
11–48–0	15	0.46	6.8
0–43–0	17	0.44	4.7
2–20–0	15	0.27	2.1
11–48–0	25	0.76	8.2
0–43–0	28	0.71	6.2
2–20–0	25	0.45	3.3
11–48–0	35	1.07	9.0
0–43–0	40	1.01	7.7
2–20–0	35	0.63	3.7
11–48–0	50	1.52	10.5
0–43–0	56	1.42	9.4
2–20–0	75	1.35	5.5

increase was less, the percentage increase remained about the same. The season of 1941, which was quite dry, showed a different result. Responses were not only less, but also more erratic in nature. Examination of Table 2 will show that the season of 1943 had no advantage over 1941 in June and July precipitation. However, the average temperatures in June and July of 1941 were definitely higher, and field notes regarding this season indicate that high temperatures occurred at the heading stage. As already indicated, the two seasons 1941 and 1943 were both rather dry, actually the average check plot yields were a little higher in 1941 (17.6 bu. per acre) than in 1943 (17.0 bu.). The difference in response in the two seasons is, however, very marked as may be seen by reference to Table 3. It is such erratic results which lead some to believe that phosphates pay as well in dry seasons as in moist, while others consider that the fertilizer has no value in a dry year. Actually, the response depends on the nature of the "dry" season. Probably the least advantage from the phosphate fertilizer is obtained when dry, hot weather occurs in the heading stage after a favourable start in spring. Cool, moist seasons appear to be favourable to the fertilized fields.

Throughout the 5 seasons of the tests, 23 trials were placed on dark brown soils, 48 on black and 4 on gray. The average increases on the dark brown and the black soils were very similar and practically the same as the over-all average shown in Table 4. It might be noted that the tests on dark brown soils were located in a part of the zone lying adjacent to the more moist black soils (Figure 1) and this may be a factor in the comparatively good results obtained on the dark brown soils. It has generally been considered that increases from fertilizer would be less on the dark brown soils than on black soils where moisture conditions were uniformly better and temperatures lower. Further experiments would be required to definitely establish that greater responses are obtainable on the black soils, but there is a definite likelihood that responses would be less erratic due to the more favourable climatic conditions of the latter zone. Only four sets of plots were located on gray soils (podzolic). The % increases tended to be a little higher on these soils, although bu. per acre increases were no higher. However, the number of plots was too small to warrant definite conclusion. Further experiments are in progress concerning fertilization of the gray soils.

As previously mentioned, among the black soils of the area there are two distinct separations which may be made and which could have significance regarding the response to phosphatic fertilizers: the high lime (rendzina-like) soils, and the non-limy normal types. However, after examining the data there appears to be only a slight difference in response on high lime soils (22 tests) compared to normal lime free soils (26 tests). The responses are slightly better on the lime free soils especially at the higher rates. For instance, the 50# application of 11–48–0 gave 10.5 bu. average increase on high lime soils, and 11.1 bu. on lime free, while the corresponding rate of 0–43–0 gave 8.7 and 9.8 bu. increase, respectively.

The statement commonly appears that sandy soils give poor responses to phosphatic fertilizers while clay soils are highly responsive. In order to see if these data gave any indication of a general trend in this connection, Table 5 was compiled. The light textured soils were fine sandy loams, and

TABLE 5.—INCREASES OBTAINED ON LIGHT, MEDIUM AND HEAVY TEXTURED SOILS

—	Rates			
	1	2	3	4
11–48–0				
Light textures	6.9	7.0	9.1	10.9
Medium textures	6.3	8 4	8.5	10.6
Heavy textures	7.7	10.4	11.4	12.0
0–43–0				
Light textures	2.9	4.9	5.4	6.9
Medium textures	5.3	6.5	8.1	10.1
Heavy textures	5.8	8.5	10.1	9.8

light loams. The heavy soils were clays and silty clay loams. In all there were 10 trials on light textured soils and 11 on heavy soils. The data in Table 5 indicate a general tendency for better response to phosphates on heavy soils than on light. This result may in part be attributed to the better moisture retention found in the heavy soils. The most marked effect is, however, the difference in response between 11–48–0 and 0–43–0 on light soils. The former is a much more efficient fertilizer than the latter for the light soils. The difference in response is much greater than that shown on the medium soils, although the heavy textured soils appear to stand intermediate in this regard. The difference in response as between 11–48–0 and 0–43–0 on light textured soils might be readily attributed to nitrogen added with the former fertilizer. As suggested by Ellis (2), light soils which have suffered from wind erosion are especially likely to benefit from additional nitrogen and undoubtedly some erosion had occurred on these soils. The better response obtained from 11–48–0 on the heavier soils may be, in part, due to the more available form of the phosphate in the ammonium phosphate, as compared to triple superphosphate, as has already been suggested. Evidence of a deficiency of available nitrogen in light textured soils after some years under cultivation has been observed, but the heavier soils appear to be always well supplied with nitrates. In this connection it should be pointed out once again that all trials were on summerfallow land which should normally have a good reserve of nitrates. In a relatively dry climate such as prevails in this region, no important loss of nitrates can occur through leaching, except on light textured soils. It is therefore difficult to account for the difference in response on medium and heavy textured soils, as between these fertilizers simply on the basis of difference in nitrogen content.

As stated above, increased tillering, somewhat darker green colours, and a generally stronger growth were commonly observed in the treated plots. However, it was only in a few cases that striking symptoms of phosphate deficiency were observed in check plots, and these only where very high increases in yield were obtained. A field near Watrous, Saskatchewan, showed the most pronounced evidence of phosphate deficiency of any observed. The untreated plants were of an unhealthy greyish blue-green colour, as if beginning to suffer from drouth, although moisture was

plentiful. Stooling was poor, the growth relatively poor and the crop was later than the treated plots by at least 10 days. In comparison with the treated plots immediately adjacent, the differences in colour, vigour and stage of maturity were most striking. The 50 lb. application of 11–48–0 gave 23 bu. increase in this field, other treatments giving corresponding increases. In general, it would appear that easily observable symptoms of phosphate deficiency in grain are not commonly encountered in this area except where direct comparisons between the growth and tillering on treated and untreated plots can be made.

Determinations of protein content and of bu. wt. were made on selected samples in each season.[1] The protein content showed no relationship to fertilizer treatment. The treated plots tended to average higher in bu. wt. but the difference was slight. The most important fact found in connection with the determination of bu. wt. was that the results were no different in the "dry" year of 1941 than in the "wet" year of 1942. The common impression that grades of wheat tend to be lower on fertilized crops in dry years, was not substantiated by these data.

SUMMARY

Results of fertilizer trials over a wide range of soils in a portion of Saskatchewan are given. The fertilizers used were of three kinds: 11–48–0, 0–43–0, and 2–20–0. They were applied at 4 rates, the rates being such that direct comparison of efficacy of P_2O_5 applied in 11–48–0 and in 0–43–0 might be made. Results showed that the 11–48–0 fertilizer gave larger increases than were obtained when the same amount of P_2O_5 was applied in 0–43–0. This difference may not be altogether attributable to the nitrogen carried in the former fertilizer. Good increases were obtained at the lowest rate of application, but greater increases resulted from the highest rate used (50# 11–48–0 or equivalent of 0–43–0). At the higher rates 0–43–0 gave comparatively better results than at the lower, and the advantage of the 11–48–0 fertilizer was therefore lessened. On lighter soils the 11–48–0 showed a more favourable response in comparison to the 0–43–0 than on medium or heavy soils. Heavy soils showed the greatest response to phosphates especially from the use of 11–48–0. The results from 2–20–0 were about proportional to the amount of phosphorus applied. The data revealed no distinct difference in response as between the dark brown and black soils, nor between calcareous and non-calcareous soils. The tendency is towards better responses in cool moist seasons, and poorer in dry, hot ones. No definite effect appeared on protein content, or in bu. wt., due to fertilization.

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[1] These results are reported by courtesy of Dr. R. K. Larmour, Department of Chemistry, University of Saskatchewan, under whose direction the determinations were made.

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BLENDING VALUE OF CANADIAN WHEAT[1]

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The improvements in soft wheat flour obtained by adding hard Canadian wheat to the mill mix are principally that the flour absorbs more water, that the dough tolerates wider variations in mixing and fermentation time, and that the loaf is larger, lighter, and of better texture. In 1933, Birchard and Aitken (2) showed with a number of European and other soft wheats that the improvements obtained in the blend were directly proportional to the amount of Canadian wheat that was added. It has also been shown (Aitken and Geddes, 1) that the blending value of Canadian wheat is directly related to its protein content. But the literature does not appear to contain a comprehensive set of data for representative commercial samples of Canadian wheat with which quantitative comparisons of blending value can be made with respect to both the percentage of Canadian wheat used and its protein content. Such data are presented in Part I of this paper.

Because of war difficulties and the present scarcity of wheat, most countries are now milling a larger percentage of the wheat kernel into flour. Whereas extraction rates of 70 to 74% were customary before the war, rates of 80 to 90%, or even higher, are now mandatory in many countries. Lengthening the extraction yields flours of progressively poorer baking quality and colour, but of increasing nutritive value provided that the extraction is not raised too far. Since long extraction flours will be widely used for the next year or two, and may be adopted permanently in some countries, it is pertinent to study the blending value of Canadian flour at different extraction levels This subject is considered in Part II of this paper. Judged by traditional methods, increasing the extraction reduces the blending value.

I. BLENDING VALUE OF CANADIAN WHEAT OF DIFFERENT PROTEIN CONTENTS

MATERIALS AND METHODS

The basic wheat used for blending with the Canadian wheat was a composite sample containing 40% of English wheat, 30% of Australian, and 30% of Argentine. This triple mix had a protein content of 10.5%. It is representative of the mix with which Canadian wheat is blended in the United Kingdom when world wheats are in good supply.

Composite samples of Canadian wheat were prepared from individual samples of grades 1, 2, and 3 Manitoba Northern taken from more than 4,000 carlots of wheat inspected in Western Canada during the 1943-44 crop year. Protein determinations were made on the individual samples and these were subsequently grouped and composited within narrow protein ranges to give 4 composite samples. The protein contents of these and

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the number of individual samples represented in each were as follows: 14.4%, 579 samples; 13.1%, 2,367 samples; 12.0%, 1,197 samples; 10.4%, 152 samples. A fifth composite with a protein content of 10.0% was obtained by compositing 6 samples of low protein wheat grown on the grey wooded soils of northern Alberta.

The 3 foreign and the 5 Canadian wheats were milled to yield (about 70% extraction) in a laboratory mill, and the 3 foreign flours were then blended in the proportions already mentioned. For the sake of simplicity this blended flour is referred to as the Triple Mix. The flours had the following protein contents: Triple Mix, 9.4%, Canadian Flours, 13.9, 12.6, 11.2, 9.9, and 9.4%.

Triplicate loaves were baked by the malt-phosphate-bromate procedure (Geddes, *et al.*, 3) from the Triple Mix and from each Canadian flour, and also from the Triple Mix in blends with 25, 40, 55, 70 and 85% of each Canadian flour. The loaves were measured for volume and scored for appearance, crumb colour, and crumb texture. Absorptions were predetermined with the aid of the Farinograph, and any adjustments found necessary were made at the time of mixing. Special attention was paid to the handling properties of the dough during fermentation and at the time of panning. The data reported are mean values for the triplicate bakings.

Results and Discussion

The relation between loaf volume and the amount of Canadian wheat in the blends is illustrated graphically in Figure 1. One curve is shown for each of the 5 Canadian wheats, and labels give the protein contents of these wheats.

The curves show that the Canadian wheat of highest protein content (top curve) is most effective in increasing the loaf volume of the blend, and that a straight-line relation exists between loaf volume and the percentage of Canadian wheat in the blend. With Canadian wheat of 13.1% protein, the rate of increase in loaf volume is also substantial, and even with Canadian wheat of 12.0% protein a definite improvement is obtained. But when the protein content of the Canadian wheat drops to 10.4%, the increase in loaf volume is negligible, even with percentages of 80% and higher in the blend; and with Canadian wheat of 10.0% protein there is a decrease rather than an increase in loaf volume. On the basis of equal parts of the Triple Mix and Canadian, which is a suitable proportioning for comparisons, the loaf volume changes from the highest to the lowest protein Canadian wheats are: + 23, + 15, + 10, + 3, and − 5%, respectively. In the blends containing the lowest protein Canadian wheat there is a sharp drop in loaf volume with the first addition (25%), but further additions cause no further reduction. Thus the baking strength of this Canadian wheat of 10.0% protein is actually lower than that of the Triple Mix even though the protein contents are much the same. Similarly, the baking strength of the 10.4% Canadian wheat is only slightly better than the Triple Mix. It is therefore apparent that Canadian wheat can be so low in protein content that it is quite unsuitable for supporting a blend like the Triple Mix.

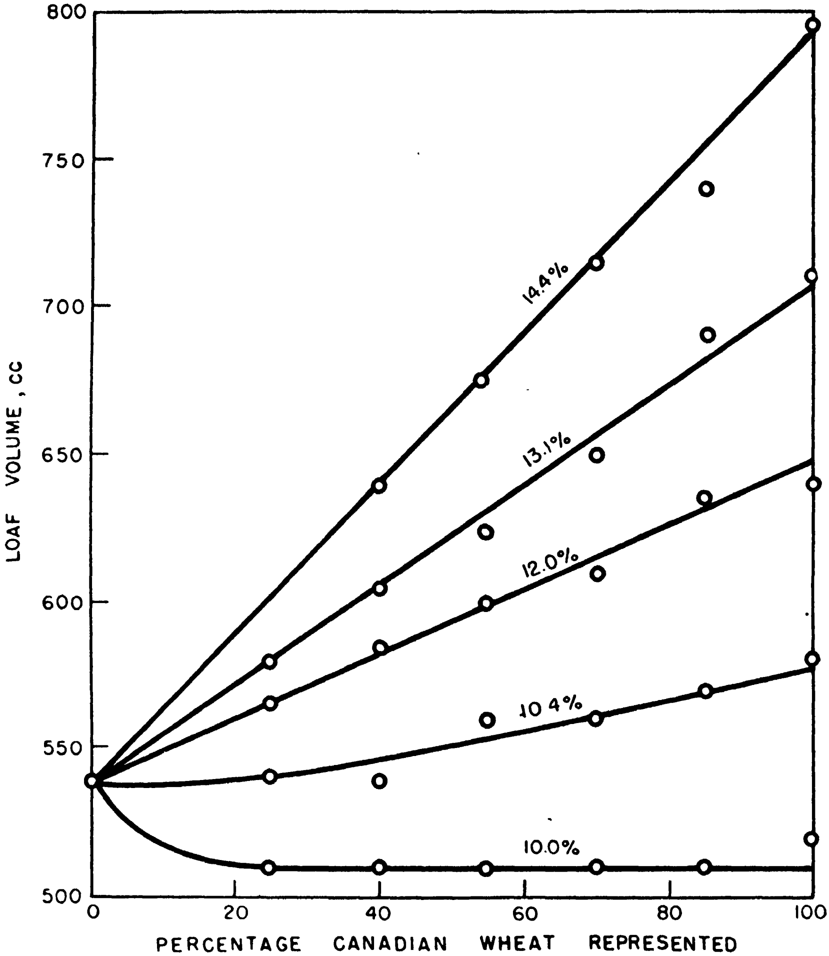

FIGURE 1. Graph showing relation between loaf volume and amount of Canadian wheat in the blends. Labels indicate the protein contents of the Canadian wheats.

When one considers that additions of Canadian wheat to weaker wheats bring about improvements other than increased loaf volume, it is possible that wheat of 12% protein might be satisfactory in mixtures for the milling of certain types of flour. But the data show that at least 80% of wheat of 12.0% protein would be required to give a loaf of the same volume (625 cc.) as 50% of wheat of 13.1% protein or 35% of wheat of 14.4% protein.

A photograph showing the loaves made from the Triple Mix alone, and from the blends containing 55% of each of the five Canadian wheats appears as Figure 2. Considerable differences are readily apparent in the volumes of these loaves.

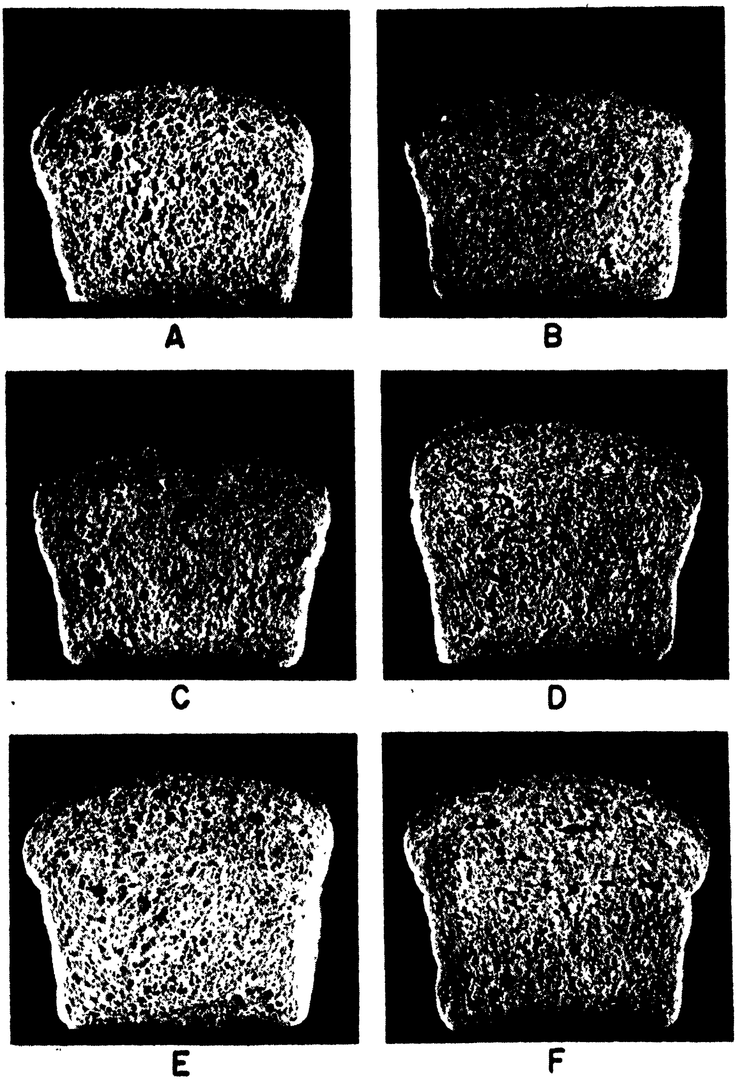

FIGURE 2. Photograph of loaves made from the Triple Mix (A) and from blends containing 55% of each of the five Canadian wheats. 10% protein (B), 10.4% protein (C), 12.0% protein (D), 13.1% protein (E), 14.4% protein (F).

The effects on protein content, absorption, crumb texture and crumb colour of increasing additions of the Canadian wheats to the Triple Mix are shown by the four graphs in Figure 3. All four graphs show essentially the same thing for each quality; viz., that the improvement obtained is directly related to the initial protein content and amount of Canadian wheat in the blend.

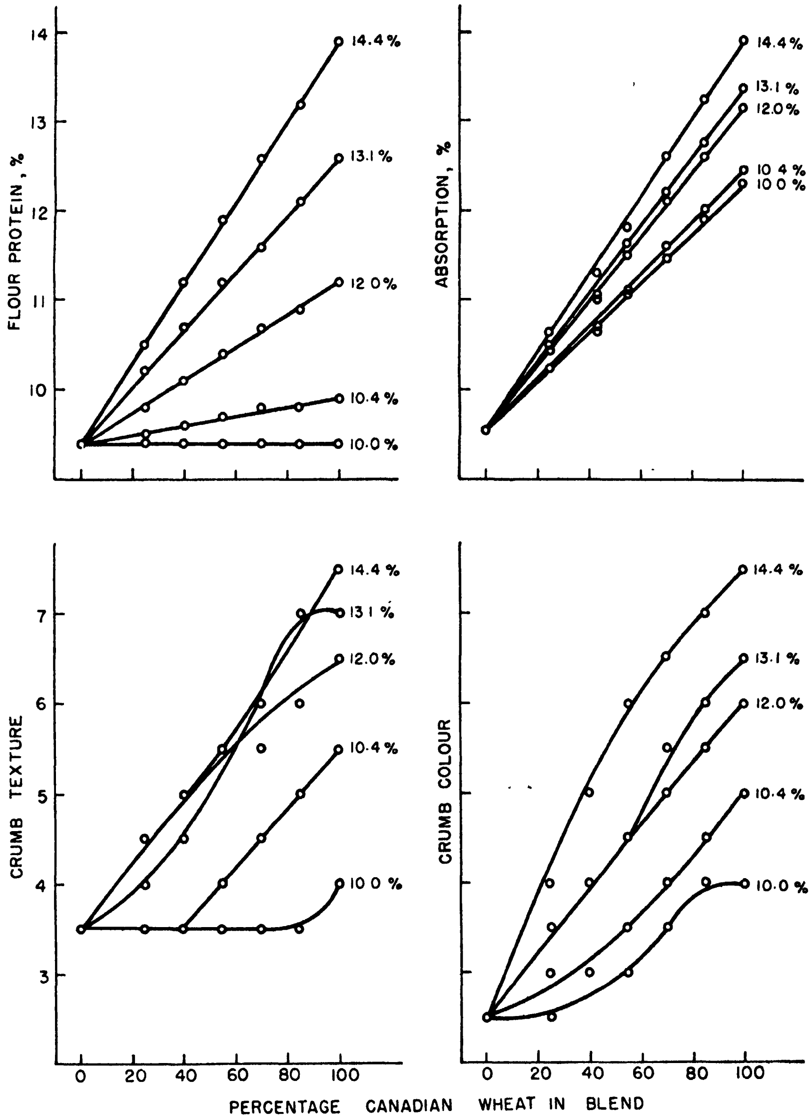

FIGURE 3. Graphs showing relation between flour protein, absorption, crumb texture, crumb colour and amount of Canadian wheat in the blends. Labels indicate the protein contents of the Canadian wheats.

The pattern of the curves for protein content bears a striking resemblance to that for loaf volume (Figure 1) except that the protein content of the blend containing the lowest protein Canadian wheat (10%) is the same for all concentrations. This would suggest that the quality of the protein of this Canadian wheat is inferior to that of the Triple Mix,

otherwise a drop in loaf volume of the latter would not have occurred when the Canadian wheat was added. The steady increase in absorption resulting from increasing additions of the Canadian wheats is of particular importance to the commercial baker, for this means that his yield of bread per unit weight of flour will also increase. This increase is obtained with the low protein as well as with the high protein Canadian wheats; for the differences in absorption among the blends are not particularly large until more than about 50% Canadian is used. In each blend improvement in crumb colour occurred with each addition of Canadian wheat and the higher the protein content the better the colour score. In the blends containing the 10.4% protein Canadian wheat, no improvement in texture occurred until 40% was present; and in the blends containing the 10% protein sample, the texture score was the same for all concentrations up to 85%. Improvement in texture was, however, quite noticeable in the blends containing the 3 other Canadian wheats, but the differences were relatively small at most concentrations.

The handling quality of the dough was greatly improved in the blends containing the Canadian wheats of 12% protein and higher, and with each addition the doughs became more lively, more springy, and more stable. But the higher the initial protein of the Canadian wheat the better was the improvement. In the blends containing the 10.4% Canadian wheat, improvement was not detected until more than 40% was added; and in the blends containing the 10% protein sample, the doughs were essentially the same—short and tender.

It is apparent from these results that the blending value of Canadian wheat, as reflected by all-round improvement in dough and loaf quality, is closely related to the initial protein content and the amount used. During the past 18 years, the protein content of Western Canadian wheat has averaged 13.6%. At this level the baking strength, of a blend of soft wheat, such as that used in these studies, will be improved by about 20% by the addition of an equal weight of Canadian wheat. A greater improvement would be expected if the soft wheat was all English, and a lesser improvement if it contained a high percentage of filter wheat such as Argentine. However, the improvement of the final blend is still more dependent on the quality of the Canadian wheat which is in turn related to its protein content. The importance of avoiding wide variations in the protein content of export shipments of Canadian wheat is thus apparent.

II. BLENDING VALUE OF CANADIAN FLOUR OF DIFFERENT EXTRACTION

In many of the countries that import Canadian flour for blending purposes, the extraction of home-milled flour for bread-making is controlled by Government regulation. This was introduced during the war and is maintained because of the extreme shortage of wheat. In Great Britian the extraction was raised to 73% in 1939 from an uncontrolled pre-war level of about 70%. In 1941 it was increased to 75% and in 1942 it was increased to 85%. It remained at this level until 1945 when it was reduced to 82.5% and later to 80%. This extraction rate was in effect for only a few months; in 1946 it was increased in two short steps to 85% and 90%. The 90% extraction is expected to be only a temporary measure and will doubtless be lowered as soon as the world wheat situation improves. Whether the

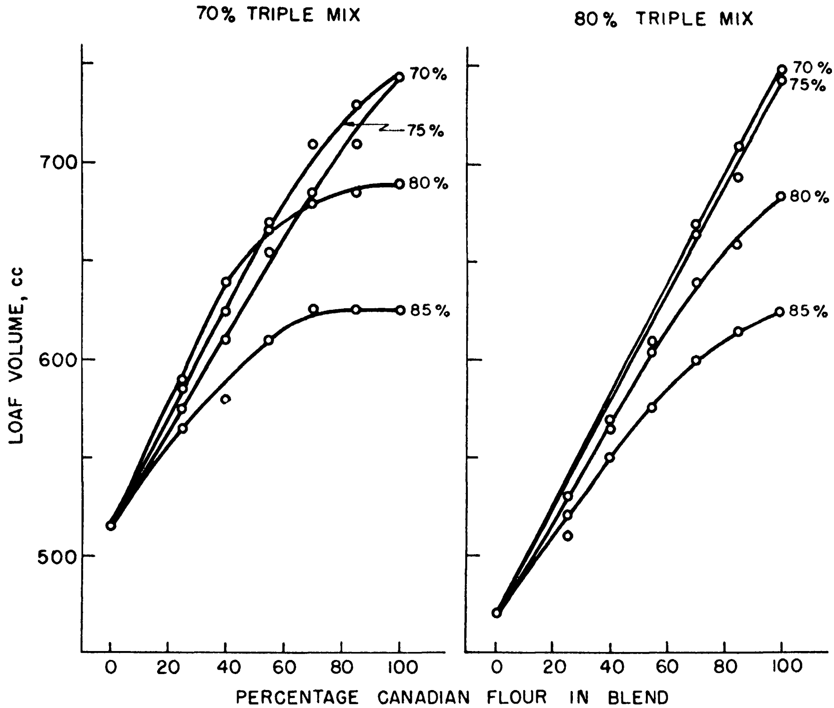

FIGURE 4. Graphs showing relation between loaf volume and amount of Canadian flour in the blends. Labels indicate extractions of Canadian flours. Left-hand group is for the blends with the 70% Triple Mix; right-hand group is for the blends with the 80% Triple Mix.

restrictions on flour extraction will be removed entirely or will be maintained at 80% or higher has not yet been decided. It therefore seemed advisable to obtain information on the value of Canadian flour of different extraction for blending with weaker flours of different extraction.

Materials and Methods

The same Triple Mix was used as in the former study, but instead of milling each wheat to yield it was milled to provide 2 flours of 70 and 80% extraction. The corresponding flours were then mixed in proportions of 40% English, 30% Australian and 30% Argentine. Ash contents were 0.57 and 0.60%.

Four Canadian flours of 70, 75, 80 and 85% extraction were used for the blending. Ash contents were 0.49, 0.54, 0.72, and 0.92%. They were milled from a wheat mix composed of equal parts 1 and 2 Northern (protein 13.3%) representing a number of cargoes of each grade shipped from Fort William in the summer of 1945. The flour extractions were chosen to provide two samples of the same extraction as the Triple Mix flours, one of intermediate extraction that corresponds to flour milled in Great Britain in the early years of the war, and one of long extraction that corresponds to flour milled during most of the war years and until quite recently. It was not possible to duplicate the dress and fineness of long

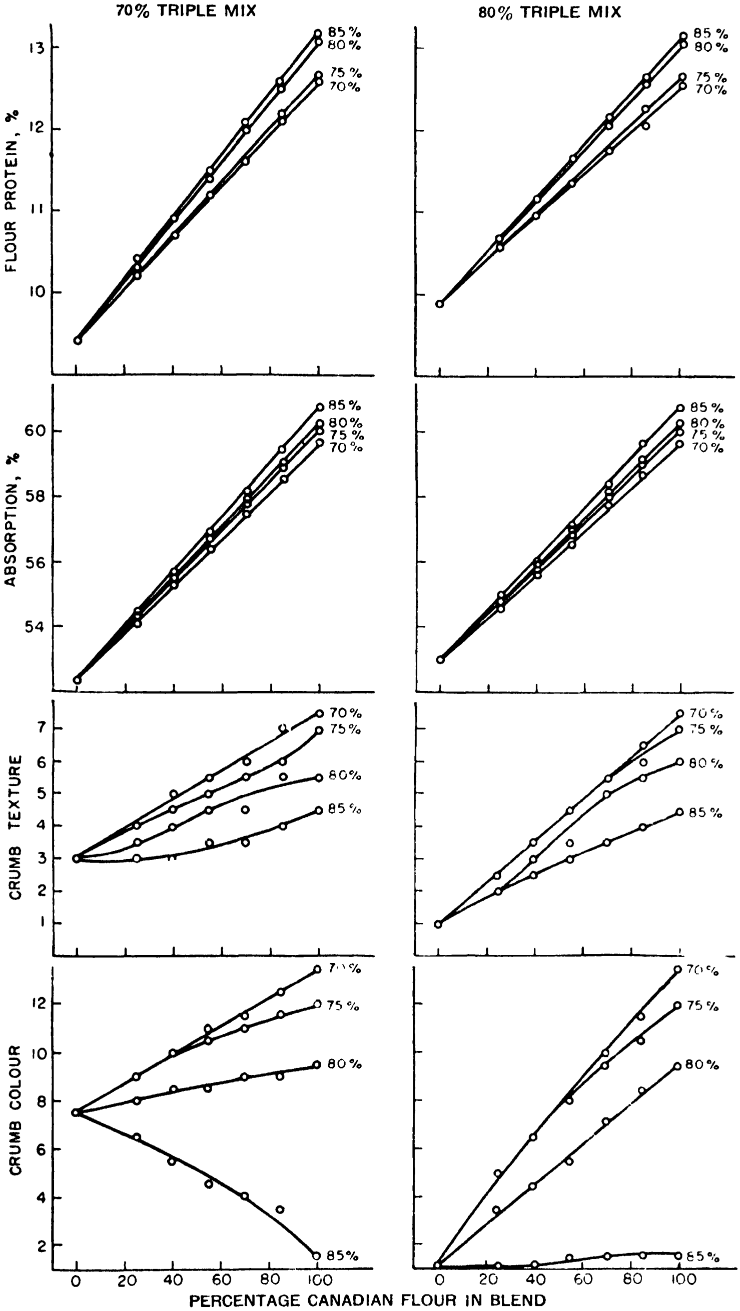

FIGURE 5. Graphs showing relation between protein content, absorption, crumb texture, crumb colour and amount of Canadian flour in the blends. Labels indicate extractions of Canadian flours. Left-hand group is for the blends with the 70% Triple Mix; right-hand group is for the blends with the 80% Triple Mix.

extraction flours now milled commercially, and it is questionable if this can be done in a laboratory mill. The increased yields were obtained by additional reduction of the fine shorts, coarse shorts, and feed flour, and for the 85% extraction by a more thorough cleaning of the bran.

The Canadian and Triple Mix flours were blended in the same proportions as in the former study and the flours were baked by the same baking method. Because of the wide range in crumb colour encountered, the range for scoring had to be widened, otherwise many of the loaves would have had negative scores. Thus a score of 7 generally awarded bread made from 1 Northern flour was increased to 13.5. This was the only change made in the scoring procedure.

Results and Discussion

The relation between loaf volume and composition of the blends is shown by the two graphs in Figure 4. The left-hand group contains 4 curves showing the effects of adding Canadian flour of 70, 75, 80 and 85% extraction to a Triple Mix of 70% extraction; corresponding curves for the Triple Mix of 80% extraction are shown on the right.

In the blends with the 70% Triple Mix (left) the increase in loaf volume is much the same for each addition of the 70 and 75% Canadian flours at all concentrations, and also for the 80% Canadian flour up to a concentration of about 55%. With the 85% Canadian flour, loaf volume is lowest at all concentrations. With both the 80 and 85% Canadian flour, additions higher than 55% were of little value; after this level, loaf volume changed little or not at all. Thus for increasing the baking strength of the 70% Triple Mix, Canadian flours of 70, 75 and 80% extraction are about equal in concentrations up to about 55%. In higher concentrations the 70 and 75% flours are about equal in value, both flours are better than the 80% flour, and all these 3 flours are better than the 85% flour. The same relations among the blends occur with the 80% Triple Mix (right) but at all levels of fortification loaf volumes are lower.

The effect on protein content, absorption, crumb texture, and crumb colour, of increasing additions of the Canadian flours to the two basic flours, is shown by the eight graphs in Figure 5. The graphs at the left are for the blends with the 70% Triple Mix; those at the right are for the blends with the 80% Triple Mix.

In both series of blends, protein content increases with each addition of each Canadian flour. Although the protein levels increase with flour extraction this is not always reflected by higher baking strength. This is due to the increasing percentage of low grade flour in the long extraction flour, and the fact that the low grade material is high in protein content but low in baking strength. In absorption, the same upward trends are found as for protein content, but the differences between corresponding blends are somewhat smaller. Thus for increasing the absorption of the Triple Mix flours, the 4 Canadian flours are about equal in value. Since, however, it is known that dough from long extraction flour loses more water during the baking procedure than dough from short extraction flour, the higher initial absorption of the former would be of little real advantage because a higher scaling weight would be required to give a loaf of the same weight.

Crumb texture improved in both series of samples with each addition of Canadian flour, and the lower the extraction the greater the improvement. The scores for the blends with the 70% Triple Mix were, in general, higher than those with the 80% Triple Mix, but the differences narrowed appreciably in the higher concentrations of Canadian flour. Crumb colour also improved in both series of samples with each addition of the 70, 75 and 80% Canadian flours and, again, the lower the extraction the greater the improvement. This was not so, however, in the blends containing the 85% Canadian flour; for with the 70% Triple Mix crumb colour became progressively poorer, and with the 80% Triple Mix it was essentially the same at all concentrations.

The doughs for the blends with the 70% Triple Mix improved in liveliness, spring, and stability, with each addition of the 70 and 75% Canadian flour, and differences were negligible between corresponding samples. With the 80% Canadian flour, improvement was not detected until 70% and higher was used, and none of the doughs equalled those containing the shorter extraction flours. No apparent improvement in dough handling quality resulted from additions of the 85% Canadian flour, and at concentrations higher than 25% the doughs were soft and tender. In the blends with the 80% Triple Mix, the same trends were found, but, blend for blend, the doughs were inferior in all-round handling quality.

The results of this investigation show that the blending value of Canadian flour is directly related to its extraction, the amount used, and the extraction of the weaker flour with which it is blended. Moran and Jones (4) state that British-grown wheat is relatively poor in baking quality and generally unsuitable for the milling of flour for bread-making, except when blended with at least an equal amount of strong imported wheat of which Canadian is the unexcelled example. It therefore seems reasonable to compare the blending value of the Canadian flours of different extraction when mixed in the 50 : 50 proportions. It will also be noted that Figure 4 shows that the curves for loaf volume are essentially linear for all the Canadian flours up to about this concentration. The baking data for the several Canadian flours in blends with equal parts of each Triple Mix flour are given in the following table:

Triple Mix (50%) Extraction	Canadian (50%) Extraction	Absorption	Loaf volume, cc.	Increase	Crumb texture	Crumb colour
%	%	%		%		
70	70	56.0	640	24	5.2	10.6
	75	56.2	655	27	4.9	10.3
	80	56.3	660	28	4.3	8.7
	85	56.5	600	17	3.3	5.3
80	70	56.3	610	30	4.2	7.7
	75	56.6	610	30	4.2	7.7
	80	56.7	600	28	3.4	5.3
	85	56.9	570	21	2.8	1.2

In the blends with the 70% Triple Mix, the loaf volumes for the 70, 75 and 80% Canadian flours are essentially the same and distinctly higher than that for the 85% Canadian flour. Although there is a downward trend in both crumb texture and crumb colour with increasing flour extraction, the differences between the 70 and 75% Canadian flours are so small that they can be disregarded. There is, however, a distinct drop in both scores for the 80 and 85% flours, particularly the latter. Dough handling quality was quite satisfactory and about the same for the two lower extraction flours, but less satisfactory for the 80% flour and much inferior for the 85% flour. Thus, for improving the all-round baking quality of the weaker flour, there is little to choose between 70 and 75% Canadian flours at this concentration. For improving baking strength only, the 80% Canadian flour would be equally as satisfactory but for other loaf and dough qualities it would be less desirable. Although the longest extraction Canadian flour increased baking strength considerably, it is the least desirable of all the flours. Essentially the same conclusions can be drawn for the blends with the weaker flour of 80% extraction, but, blend for blend, dough and loaf qualities are distinctly inferior. However, the percentage increases in loaf volume are generally slightly higher, blend for blend; thus, relatively, the Canadian flours improved the baking strength of the longer extraction Triple Mix equally as well as they did the shorter extraction Triple Mix.

In the Report of the Conference on the (British) Post-war Loaf (5), it was unanimously recommended that National Flour of 80% extraction should be maintained for the time being, and the feasibility of importing only flour of similar extraction was also considered. It is therefore of interest to compare the baking quality of the 70% extraction Canadian and Triple Mix flours with that of the 80% extraction Canadian and Triple Mix flours using a blend of equal parts of each flour for the comparison. The data show that, while absorption is essentially the same, baking strength, crumb texture, crumb colour and dough handling quality are distinctly better for the shorter extraction blend. Improvement in baking strength (loaf volume increase of the weaker flour) is, however, somewhat greater for the higher extraction blend. If the future trend in milling is toward long extraction (about 80%), the most noticeable effect on baking quality will be inferior dough handling quality and less pleasing internal loaf characteristics.

SUMMARY

This paper is presented in two sections dealing respectively with the blending value of Canadian wheats of different protein content and of Canadian flours of different extraction. In the wheat study, increasing amounts (25, 40, 55, 70 and 85%) of 5 Canadian wheats, having protein contents, of 10.0, 10.4, 12.0, 13.1 and 14.4%, were added to a "weaker" blend (10.5% protein) composed of English (40%), Australian (30%), and Argentine (30%) wheats.

The blending value of Canadian wheat, as reflected by all-round improvement in dough and loaf quality, is directly related to the initial protein content and to the amount used. The results of this study indicate that Canadian wheat of 12% protein content is not suitable for giving adequate support to weaker wheat, and to obtain the best results, wheat of

higher protein is required. A protein content of around 13% would be a satisfactory minimum; for an addition of 50 to 60% gave a fairly large loaf with reasonably good internal characteristics and dough of satisfactory handling quality. Similar levels of quality were obtained with about 30 to 40% of wheat of 14.4% protein.

In the flour extraction study, the same increasing amounts of 4 Canadian flours of 70, 75, 80 and 85% extraction, milled from wheat of 13.3% protein, were added to flours of 70 and 80% extraction, milled from the weaker blend described above. The blending value of Canadian flour is directly related to its extraction, the amount used, and the extraction of the weaker flour with which it is mixed. For improving the all-round baking quality of a weaker flour of 70% extraction, there is little to choose between Canadian flours of 70 and 75% extraction; for improving baking strength only, flour of 80% extraction would be equally as satisfactory up to a concentration of about 55%. Although Canadian flour of 85% extraction increases baking strength considerably, it is the least desirable of the several flours investigated. Essentially the same conclusions apply for corresponding blends containing weaker flour of 80% extraction but, blend for blend, dough and loaf qualities are distinctly inferior. As indicated by the percentage increase in loaf volume, the Canadian flours improved the baking strength of the longer extraction flour equally as well as they improved the shorter extraction flour. If the trend in milling is toward longer extraction, the most noticeable effect on baking quality will be inferior dough handling quality and less pleasing loaf characteristics.

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THE INFLUENCE OF SPRAY PROGRAMS ON THE FAUNA OF APPLE ORCHARDS IN NOVA SCOTIA: I. AN APPRAISAL OF THE PROBLEM AND A METHOD OF APPROACH[1]

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INTRODUCTION

In Nova Scotia, as elsewhere, the economical control of apple orchard insects is becoming progressively more difficult. During the early part of this century, fruit of good quality was produced with 2 or 3 applications of spray applied with hand-operated pumps. To-day, with greatly improved equipment and spray chemicals, 6 to 10 applications are required to produce crops reasonably free of insect damage. For the most part, the species of insects now creating the major control problems were of minor importance in the earlier days. An understanding of the bases of these phenomena now challenges the research ability of economic entomologists.

Kelsall (7) has recorded the general trend in the development of orchard sprays in Nova Scotia during the 30-year period beginning in 1908. Briefly, at the beginning of this period, the spray program was based on Bordeaux mixture for the control of apple scab, together with an arsenical as insecticide. The major insect pests at that time were canker-worms, tent caterpillars, budmoths, codling moth, green fruit-worms and tussock moths. While reports indicate that budmoths and codling moth were then important pests, there is reason to believe that they were not as injurious as in recent years.

Following 1910, lime sulphur partially replaced Bordeaux mixture, mainly in order to reduce the amount of fruit russeting which followed the use of Bordeaux mixture near the time of bloom. About this same period, lead arsenate came into common use and power sprayers were introduced.

Beginning about 1918 the practice of orchard dusting became common and reached its height about 1924. Both sulphur and copper-lime dusts were used along with lead or calcium arsenate. Lime-nicotine sulphate dust was also introduced as a contact insecticide during this period. Kelsall (7) has pointed out that the extensive use of dusts was terminated mainly because of extreme outbreaks of the eye-spotted budmoth, *Spilonota ocellana* (D. & S.), and the appearance of the European red mite, *Metatetranychus ulmi* (Koch) (*Paratetranychus pilosus* (Can. & Fanz.)), as a serious orchard pest.

During the next few years modified lime sulphur sprays came into general use to be in turn gradually replaced by elemental sulphurs. Both calcium and lead arsenates, as well as nicotine sulphate, continued to be employed. Dormant oils were used extensively during the latter half of the 1930's for the control of the oystershell scale, *Lepidosaphes ulmi* (L.).

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During this period of development of spray practices, such formerly well-known pests as the cankerworms, fruitworms and tent caterpillars became of minor importance in commercial orchards. Others such as the eye-spotted budmoth and the codling moth increased greatly in importance. Still others, including the gray-banded leaf roller, *Argyrotaenia mariana* (Fern.), and the European red mite which were not mentioned in the earlier literature have now become major pests. There are some references to oystershell scale on apple in the literature previous to 1900; it apparently was of minor importance from about 1900 to 1930, but has since increased until it is now a major pest.

METHODS OF APPROACH TO PEST CONTROL PROBLEMS

The approach to the problem of insect control has been influenced by the traditional method of compartmentalizing fields of investigation. There is a tendency for horticulturists, soil specialists, plant pathologists and entomologists to proceed independently with their own special lines of research without properly integrating the results of one with the other and with the whole problem of apple production. There has also been a tendency for entomologists to believe that the spray method could be made to deal adequately with the whole field of apple insect control and they have thus left other avenues of investigation insufficiently explored. Dr. F. H. Lathrop, remarked at a conference of entomologists of Maine and the Maritime Provinces held at Fredericton on January 23, 1941, that "It is possible that if spraying had never been introduced we would still have found ways of growing good apples."

The pressure on economic entomologists for the prompt elimination of apple pests has encouraged them to take a short-term view of insect control problems. Investigators consequently aimed at the development of spray programs to control those pests of immediate importance, with little or no regard to other organisms which at the time seemed of little consequence. A fungicide, for instance, might be applied to control apple scab, and any control it might exert on other pests was deemed an additional asset, but little or no attention was paid to its influence on the total fauna and microflora of the environment into which it was projected. In addition, replication of experiments in the same orchard for several years was seldom practised, so that there was no long-term measure of the effect of a spray program—the effect not only on pests but also on those insects, mites and other organisms of direct or indirect importance in natural control.

Examined from another viewpoint, the traditional approach may be criticised for not effectively applying ecological concepts and methods to the problems of economic entomology. This situation has continued in spite of the fact that ecologists and some entomologists have, from time to time, emphasized the importance of the ecological aspects of economic entomology. As long ago as 1915, Forbes (6) pointed out that, "It is not because we do not know what we commonly call the *entomology* of the chinch-bug and the Hessian fly and the white-grubs and the cotton-moth that we are so nearly at our wit's end in our efforts to devise means for their control; it is because the knowledge of their entomology merely is not sufficient for the purpose . . . . . for the purposes of this discussion at any

rate, the subject matter of ecology may be defined as the relation of organisms to their environment, and that this means the *whole* environment, organic and inorganic, and any and *all* organisms, man included . . . . the economic entomologist is an ecologist pure and simple, whether he calls himself so or not." Again, Townsend (11) in 1926, expressed the same viewpoint when he wrote, "Environmental investigations furnish the only sure basis for work leading to the speedy discovery of proper measures for the control of insects whether for the suppression of injurious forms or for the extension of beneficial ones. . . . . . The most perfect control in all cases consists in manipulating certain factors of the environment with reference to the insect in question." Allee (1) in 1927 pointed out the need of studies to determine the factors which cause stability or instability in biotic communities. He says, "A knowledge of such interrelationships within the community is essential for a real understanding of animal life in nature and should precede any attempt to tamper with a community by applying artificial conditions made necessary by modern economic work." Taylor (10) in 1935 wrote: "The interrelationships between the members, plants and animals, of a biotic community are vital, not incidental . . . . . . Disturbance of a single important species of plant or animal is likely to have far-reaching effects on many or all other plants and animals."

Since the preparation of this article was begun there has come to hand a most significant paper by Nicholson (8). This article outlines a theoretical basis for an approach to the problem of insect control which is similar to that which the present authors are attempting to put into practice. While we do not wish at this time to take sides in the current discussions dealing with the factors governing the density of insect populations, which have been indulged in by some writers, the authors of the present paper agree in principle with Nicholson's theoretical approach to the study of the relationship of sprays to insect populations. As Nicholson says, "There is no simple answer to this question, for the addition of a new factor to a complex equilibrium system may cause ultimate effects which are entirely different from the direct effects of the new factor." It is important that these different factors be recognized and their significance appreciated.

It would appear that a valid challenge has been presented by these and other writers and that this challenge has been largely ignored by economic entomologists. It is time that its implications were accepted and acted upon. The present status of our orchard pest control problems makes it necessary to explore the possibilities of a more dynamic method of approach. There is no denying the fact that such an approach presents tremendous difficulties, both because of the complexity of organic and inorganic interrelations which must be explored, and because of the formidable requirements in terms of increased quantity and quality of personnel and material requirements.

OUTLINE OF INVESTIGATIONS IN NOVA SCOTIA

In order to determine the effect of the various spray chemicals on the pest control problem of Nova Scotia orchards, a series of long-term experiments are now underway. Many problems are involved in selecting orchards suitable for studies of this kind. In order to study population

relationships that exist before any spray is applied, and then to follow the succession of changes which occur as spraying is continued from year to year with the same materials on the same block, orchards in a state of neglect are used. To complement such studies, commercial orchards, in which special pest problems exist, are selected. These orchards have been conditioned by a spray program so that the various species are at different population levels from those of unsprayed orchards. As a new spray program is applied to such an orchard for several years any changes in population can be observed. The fact that the course of these changes may be quite different in each of these two types of orchard, necessitates the use of both.

Insofar as is practicable, individual spray chemicals are studied separately. Since observations made over a period of years suggested that the fungicides commonly used in Nova Scotia had a pronounced effect on the prevalence of certain pests, our attention has been largely devoted to a study of their effects because, under Nova Scotia conditions, fungicides must be used to control apple scab.

The methods to be used in recording population changes of many species are by no means fully evolved, and will be modified as conditions require. The essential basis of present methods is the taking of periodical numerical records on as many species as possible. These are taken, for the most part, directly in the field and usually with the aid of binocular microscopes. Experience soon showed that many of the organisms could be grouped, on the basis of numbers and mobility, so that their populations could be determined simultaneously by examination of a unit of a certain size. For example, many species of mites and their eggs, certain insects and insect eggs may be recorded at one time by examination of a specified number of leaves, but this number may not be large enough for more sparsely distributed forms such as budmoth or codling moth eggs or such very mobile forms as mirids, which need to be counted separately or along with another group. Still another grouping includes larvae, such as leaf rollers, budmoths, leaf miners, etc., as well as their larval and pupal parasites. Records of very active insects may be taken by examining a number of trees in each plot for a specified length of time. This method is used, for instance, in measuring the numbers of adult *Aphelinus mytilaspidis* LeB., an important parasite of oystershell scale. Still another and very promising technique is that of dusting a different tree in each plot periodically with a quick-acting dust and collecting the affected arthropods on trays of measured area.

Further details will not be given here as they will be covered in later papers dealing with individual species. An indispensible adjunct to detailed counts is general observation, for, as Allee (1) has pointed out, "An obvious method of supplementing and expanding the data of statistical ecology is by plain, intelligent observation. We need at the present time such field observations on the interrelations of members of insect communities by gifted observers more than we have ever needed them because now they can be of immediate importance as well as of interest. . . . . . The method is time-consuming but may yield illuminating results without which the data from modern statistical and experimental work cannot be correctly interpreted, if indeed they can be successfull collected."

To supplement the field studies, a number of small trees have been caged and adult codling moths and budmoths placed within to build up large populations of eggs. The cages are then removed and periodical counts made on the condition of the eggs and larvae, and as much as possible of the other fauna of the trees. A certain amount of insectary work has been done in rearing immature forms for identification, but this work should be expanded to gain a more intimate knowledge of the life histories and habits of many species.

BRIEF DESCRIPTION OF EXPERIMENTS

As detailed experimental results will be included in future papers, only a brief description of the various experimental orchards and treatments as well as short notes on the more evident trends in faunal populations will be given here.

Hiltz—South Yarmouth Orchards, Berwick

This is a 10-acre block, about 35 years old, chiefly of Baldwin, Gravenstein, Golden Russet, Wagener and Northern Spy. It is cultivated with a sod strip along the tree rows. As the soil is a light gravelly loam, the orchard suffers somewhat from drought in dry seasons, and the trees are therefore of only moderate size and past their prime bearing condition. It is surrounded on all sides by sprayed orchards.

This orchard was selected because it had the worst infestation in the area generally most heavily infested with codling moth. It was used for experimental purposes for some years previous to the establishment of the present project and its history is well known.

Since 1943 the north half of the block has been treated with copper sprays and the south half with sulphur sprays. Three pre-blossom fungicidal sprays without an insecticide are applied each year, followed by 3 post-blossom sprays containing 3 pounds of lead arsenate per 100 Imperial gallons of the fungicide spray; by 1 straight lead arsenate spray; and finally by 2 applications of cryolite, making a 9-application program.

Among the more significant results observed to date are the following:

(1) In the copper-sprayed portion, the European red mite has practically disappeared. This is evidently due to the establishment of effective populations of predators which include predacious mirids, the predacious mite *Seiulus* sp., and the thrips *Haplothrips faurei* Hd. The clover mite, *Bryobia praetiosa* K. increased to some extent on this plot but was later controlled mostly by the raphignathid mite, *Mediolota novae-scotiae* Nesbitt and probably also by mirids and *Haplothrips faurei*. Very little red or clover mite survived to overwinter in 1944 or 1945.

(2) In the sulphur plot, the European red mite has persisted as an important pest. While the sulphur sprays probably gave some control during the spraying season, a build-up in population took place after spraying was discontinued, so that each year a substantial population of red mite appeared in late August and early September on this plot, which stood out in marked contrast to the copper-treated section. Later in September and October the winter eggs of the mite were heavily fed upon by *Haplothrips*

faurei. There is some evidence that this predator does not thrive under a sulphur spray program and that it was attracted to this part of the orchard by the large numbers of red mite eggs after considerable weathering of the sulphur sprays had taken place. While its origin is not certain it apparently migrated to some extent, at least, from the copper-treated area. The predacious mite *Seiulus* sp. was practically absent from this section of the orchard and was apparently suppressed by the direct effect of the sulphur. The mite, *Mediolota novae-scotiae* which is such an important predator on the clover mite, was also absent. The clover mite is presumably controlled directly by the sulphur since it did not occur in the sulphur plot.

(3) At the time the treatments were started the population of the oystershell scale, *Lepidosaphes ulmi* (L) was very low in this orchard. During 1943 and 1944 there was very little change, but in 1945 a marked increase occurred in the sulphur plot. Records taken from 37 Baldwin trees in the copper plot showed an average of 2.3 scales per 100 inches of new growth, whereas a similar record from 38 Baldwin trees in the sulphur plot gave an average of 102.6 scales. The probable reason for this difference will be discussed in connection with the work in the Palmer orchard.

Palmer Orchard, Berwick

This is a block of nearly 5 acres of trees about 30 years old, predominantly Stark, Cox Orange Pippin, Northern Spy and Ben Davis. This area forms about ⅓ of a larger orchard, the balance of which is cared for entirely by the owner. The experimental block is surrounded by sprayed orchards on three sides and by a small area of pine woods on the fourth. The soil is a deep, fairly light sandy loam and is not affected by drought to any marked extent. The trees have been well cared for and are growing vigourously. The soil is cultivated in the spring by discing.

This orchard was selected because of a fairly heavy infestation of oystershell scale and treatments were started in 1943. Four fungicides have been included in the tests, namely, lime sulphur, flotation sulphur, copper (Bordeaux mixture and fixed copper being used on the same plot) and the organic fungicide, ferric dimethyl dithiocarbamate (Fermate). Lead arsenate has been used as an insecticide in all sprays following the bloom. Throughout the course of the tests it has become evident that both forms of sulphur almost entirely prevent the development of the mite *Hemisarcoptes malus* (Shimer), which is an important predator of the oystershell scale and which if not suppressed will ordinarily keep this pest under control. This predator develops freely under the Fermate treatments and is evidently only slightly, if at all, suppressed by copper treatments. Similar effects have been noted on the development of the parasite *Aphelinus mytilaspidis* which attacks the oystershell scale. This parasite develops freely on both the copper and Fermate plots throughout the season but is found on the sulphur-treated trees only after this material has undergone weathering for several weeks. Flanders (4 and 5) observed in California a similar effect on the parasite, *Metaphycus helvolus* (Compere), which attacks the black scale, *Saissetia oleae* (Bern.). Cox (3) also noted that dormant lime sulphur sprays were lethal to the parasites of the San Jose and terrapin scales.

After 3 years' treatment, the oystershell scale has practically disappeared from the Fermate-treated trees, and has been greatly reduced on those treated for only 2 years. Table 1 gives the results obtained with the various treatments used.

TABLE 1.—OYSTERSHELL SCALE ON SPRAYED TREES

Changes in oystershell scale population per 100 in. of new growth	% of 1945 scales* dead before oviposition
On Fermate after 3 years treatment from 759 to 1	99.7
On Fermate after 2 years treatment from 284 to 67	93.8
On lime-sulphur after 2 years treatment from 66 to 91	72.2
On copper after 2 years treatment from 382 to 39	79.6
On flotation sulphur after 2 years treatment from 156 to 413	25.4

* These figures include only those scales which became established on the new growth.

Results from treatment for 2 years with copper sprays are very similar in that the scale problem is well on its way toward elimination. Lime sulphur plots, after 2 years' treatment, show no marked change in scale population, probably because this chemical itself directly controls oystershell scale to a marked extent when used throughout the spraying season. Nevertheless, a moderate population of healthy scales still persists. On the flotation sulphur plots there has been a definite increase in the scale population where the treatments have been continued for 2 years; there are practically no predacious mites and only a small number of *Aphelinus*. It is of interest to note that this orchard is divided into single and double row plots and that the parasite and the predator have remained confined to the Fermate and copper-treated plots throughout their several generations. However, the last generation of adult *Aphelinus* may migrate into the sulphur-treated plots in September, with the result that overwintering larvae of this parasite may be almost as abundant on sulphur-treated trees as on those treated with copper or Fermate.

Extensive records have been taken on the fluctuations of the European red mite populations in this orchard but the plots are apparently too small to give clear results. The high degree of mobility of many of the important predators of this mite considerably modifies the differential effects of the various spray chemicals on their development.

Drew Orchard, Berwick

This is a 2-acre block surrounded on three sides by sprayed orchards. The trees are about 30 years of age; on the whole, they have been poorly cared for and are small for their age. The soil is a gravelly loam and the trees are affected by drought in dry seasons. The orchard is situated about ¼ mile from the Hiltz-South Yarmouth block and is on a similar type of soil. When the experiments were started in 1944 the trees had been unsprayed for about 10 years.

Fungicides alone have been put on three different groups of trees and one group has been left without treatment. The fungicides used were flotation sulphur, copper and Fermate. The following are some points of interest noted in this orchard:

(1) Unsprayed trees were characterized by a large number of arthropod forms, this condition being most striking in regard to Acarina. Among those found on the leaves of unsprayed trees are phytophagous species such as the European red mite, the clover mite, the red spider, *Tetranychus bimaculatus* Harvey and Eriophyids. Other forms found on leaves include the predacious mites, *Seiulus* sp., *Anystis* sp., *Mediolota novae-scotiae*, and two species of Bdellidae. There are also a number of others of no apparent direct importance such as *Czenspinskia lordi* Nesbitt, *Tarsonemus* sp., and *Tydeus robustus* Bks. Many other species not listed above are found on the trunk, limbs and twigs. These appear for the most part to be scavengers but one, *Hemisarcoptes malus*, is a most important predator on oystershell scale.

(2) The copper-sprayed trees did not differ greatly from the unsprayed trees. There was no marked build-up of European red mite and clover mite, in direct contrast to what ordinarily happens when the change is first made from sulphur to copper sprays. Most of the species of mites found on unsprayed trees were able to survive copper spray treatment.

(3) On the Fermate plot a slight build-up of clover mite and an appreciable increase in European red mite took place. Both decreased later in the season. There were indications of some interference with natural conditions but these were not so marked as with sulphur.

(4) The sulphur-sprayed plot showed a marked reduction in the general mite populations and a number of species, some known to be beneficial, were practically eliminated. European red mite was kept to a fairly low level during the spraying season but increased markedly after spraying was discontinued. *Haplothrips faurei* appeared in considerable numbers in the fall and destroyed many of the eggs.

(5) There was less parasitism of the eggs of the eye-spotted budmoth, *Spilonota ocellana*, by *Trichogramma* sp. on the sulphur plot than in the other treatments or the unsprayed plot. This was consistent during the 2 years that the experiment has been underway. Schread and Garman (9) in Connecticut have recorded similar results with *Trichogramma* on the oriental fruit moth.

Wolfe Orchard, Waterville

This orchard had been badly neglected for many years and at the time the experiment was started in 1944 birch saplings were growing higher than the 30 year old apple trees. It consists of a block of several acres in the vicinity of large areas of commercially sprayed orchards. The soil is a gravelly loam on which the trees are not seriously affected by drought. The soil has been uncultivated but during the 2 years the experiment has been underway the trees have been well fertilized.

The fungicide Fermate has been used alone on a block of about 1 acre in this orchard and the balance has been left unsprayed as a check plot. The following are some of the points of interest noted so far:

(1) The European red mite has not increased to any extent on the Fermate plot during the 2 years.

(2) There was a slight increase in the clover mite population, possibly due to the fact that the afore-mentioned raphignathid mite *Mediolota novae-scotiae* was inhibited by Fermate. The records suggest that most of the other mites were not seriously affected. *Haplothrips faurei* was numerous in August, 1945, on both the unsprayed and sprayed plots.

Aldershot Orchards, Kentville

These are four blocks of moderately young orchard belonging to the Aldershot military camp, each fairly well isolated from any other orchard in the vicinity. These orchards, neglected for 5 years previous to 1945, were made the basis for a long-term experiment to measure the population changes brought about by the continued use of some common spray materials over a period of years. During 1944, some preliminary population studies were made and all through the growing season of 1945 records were kept of the insect and mite populations. Some changes in population status have occurred but a discussion of these will be left for a later paper after more information has been gathered.

On one of these blocks, consisting of 8 acres mostly of Ben Davis but with a few Wealthy, a Fermate program is being used, with the addition of lead arsenate on half of the block. A second block of 3 acres of Stark and Ben Davis is being treated with flotation sulphur, without an insecticide. Another 1½ acre block of Ben Davis and King of Tompkins is being treated with copper sprays without an insecticide. The fourth block consists of 3 acres mostly of Ben Davis and here the ground and the trees were treated with sodium dinitro-o-cresylate (Elgetol) in the dormant period. This was followed by a Fermate program without an insecticide. Owing to delivery difficulties, no sprays were applied to the Fermate areas until the trees were in the pink stage, but the application of Elgetol reduced the early infection of apple scab to such an extent that the trees nevertheless retained a dense foliage throughout the season. This was in direct contrast to the other Fermate block which was seriously infected although it was treated the same except for the lack of the Elgetol spray.

Experimental Station Orchard, Kentville

This is a variety test orchard of 200 trees about 25 years old, at the Dominion Experimental Station. There are a number of varieties including many of the various strains of Delicious. This orchard is on a deep, fertile loam soil in a good location and except on one side is surrounded by other sprayed orchards which belong to the Experimental Station.

The sprays have been applied by the staff of the Experimental Station while the faunal records were taken by the staff of this laboratory. The spray program follows the regular Nova Scotia schedule of 3 Bordeaux and 3 sulphur applications, but in place of lead arsenate, DDT was added to the pink and the 2 cover sprays. No insecticide was used in the other applications. The interesting feature in connection with the population studies in this orchard was the tremendous build-up of European red mite and the almost complete absence of the predators of this mite. The effect on the mite and its predators was similar to that of sulphur but the violence of the action was decidedly greater and predators did not appear so promptly after spraying was discontinued. In fact the small amount of predation that had occurred up to the end of October was due only to an unidentified species of anthocorid, aphis lions and *Seiulus* mites.

DISCUSSION

This paper is merely a progress report on the methods being employed and on the more outstanding results. The work to date has been largely of an exploratory nature, and it is not suggested that the investigation is all-inclusive or that the methods should not be modified, and, in fact, it would appear that considerable modification will be necessary. The greatest weakness in present procedure is that small plots have only a limited value. Valuable results have been obtained from these small plots on pests with low powers of mobility, such as oystershell scale and mites, but when winged insects are considered, the area under observation should be much more extensive. How large the test area should be will vary with each insect, but in some cases would probably need to be hundreds of acres in extent. Not only does the mobility of the pest need to be taken into account, but also the mobility of the parasites and predators. This has been well illustrated in the studies on oystershell scale; where there was an opportunity for the parasite *Aphelinus* to develop during the summer on copper or Fermate-sprayed trees, adults of the last generation very promptly migrated to nearby sulphur-sprayed trees in September. This was in direct contrast to the predacious mite, *Hemisarcoptes malus*, which is very sluggish in its movements, and remained almost entirely absent from sulphur sprayed trees even though it might be very numerous on an adjoining tree.

There is no minimizing the difficulties involved in conducting an investigation of the scope outlined in the foregoing. In order to make it a success it will have to be approached in the spirit set forth by Ball (2) when he said: "We need more of the Spirit of Research—the inquiring mind the spirit that subjects all statements to analysis before acceptance the spirit that holds all truths as simply the best deductions from the evidence available but subject to modification at any time on the basis of new evidence. Such a spirit welcomes constructive criticisms and invites co-operation. Such a spirit grows and expands with the increasing knowledge and is ever young and up-to-date."

SUMMARY OF RESULTS TO DATE

In the short time that this project has been underway, distinct faunal differences have shown up in orchards treated with sulphur, copper and Fermate sprays. It may be safely stated that, in general, there is a much smaller number of species of arthropods on sulphur-treated areas but not necessarily a smaller number of individuals. This is particularly true of the mite fauna, most species being practically eliminated from sulphur-sprayed trees. On the other hand, the European red mite, as a result of the repression of natural control agents, may become very numerous after the spraying season. On blocks which have had a copper spray program there is much less interference with the arthropod fauna so a much larger number of species occur, but with fewer individuals than on sulphur-sprayed trees. On Fermate-treated trees there is probably more repression of the fauna

than where copper is used but not nearly as much as on the sulphur-treated areas. As stated above, sulphur represses a large number of species which include beneficial forms. Because of this, a change to a less harmful material such as copper or Fermate sprays may at first result in an increase of some species until their natural control agents become established. Experiments to date have shown that the oystershell scale outbreak which developed in Nova Scotia since 1930 was due to interference with the natural control of the scale by the use of mild sulphur sprays which repress the parasites and predators but have little effect on the scale itself. When sulphurs, and other spray chemicals which have a depressing effect on the parasites and predators of the scale, are replaced by copper or Fermate the scale population is soon decimated.

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AGRONOMIC TERMINOLOGY[1]

The Committee on Agronomic Terminology of the Western Canadian Society of Agronomy presented to the annual meeting of that organization, a brief report on some agronomic terms which had been submitted to it for consideration. Some of these terms proved to be words which may or may not be used synonymously; there were others which have been coined during recent years and have been used more or less interchangeably with older, less embracing word forms. This committee has endeavoured to define these words in order to reduce to one the number of terms which could be applied to a given case or circumstance.

A number of words, with their accompanying definitions, were proposed to the general meeting. The words and definitions were discussed, amendments made where necessary in the definitions, then a vote taken as to whether or not they were acceptable to the members present. These words and their accompanying agronomic definitions, are being published in order to bring them to the attention of other agronomists. Anyone objecting to any of these terms or their definitions, in whole or in part, or wishing to submit other terms for consideration is requested to communicate with any member of the committee.

Association

Is essentially synonymous with *correlation* but is applied when the data are obtained in *descriptive* categories or in *numerical* categories which are of unequal magnitude.

Companion Crop

Nurse crop is commonly used in Canada to denote a grain crop in which forage crops are sown, and it is believed by many to denote a beneficial plant relationship. While this may be correct in specific instances, it has been found that, at least under prairie farming conditions, there is often a serious competitive effect which results in poor stands of the forage crop being obtained. The Committee on Crop Terminology of the American Society of Agronomy[2] has proposed the term *companion crop* as more accurately describing the existant relationship.

Correlation

Study of the simultaneous variation of two or more variates when the categories are numerical and of *equal magnitude.*

Forage

Used as a noun it is coming into general use as descriptive of all edible plants either suitable for hay or for the maintenance of live stock under range or pasture conditions. It embraces plants which fall in the category of *herbage.* The latter is a collective term embracing only those seed plants without woody stems which die back to the ground after flowering.

[1]Report presented to the annual meeting of the Western Canadian Society of Agronomy, held in Winnipeg, Manitoba, June 19, 1946.

[2] Crop Terminology. Jour. Amer. Soc. Agron. 35 : 1053-1055. 1943.

Herbicide

Descriptive of numerous sprays and dusts recommended for application to and eradication of higher plants. The degree of selectivity[1] depends upon the concentrations applied and the characteristics of the plants themselves, e.g., depth of root penetration, wettability of the leaves, position of the growing point. The variety of terms appearing in popular literature, e.g., selective herbicide, hormone spray, weed killer, etc. are therefore but variations of the original term *herbicide.*

Plot

Any small unit of land used for experimental purposes. *Plat* is sometimes used as the equivalent in U.S. literature. It is of Old English origin and its use offers no advantage.

Replication

This term has been the cause of much argument. In the strictest grammatical sense it is incorrectly used. Nevertheless it is believed that it would be unwise to attempt the introduction of any other word to replace *replication*, for it is so much a part of our experimental language. Therefore the generally accepted definition is endorsed in this report. Replication may be used to denote the original set, or one or more repetitions of that original set, of treatments, varieties, etc.; thus we can speak of one, two, or more *replications.*

Rhizome

This is the accepted botanic term for horizontal under-ground stems often erroneously spoken of as creeping or running roots. It has been adequately defined in botanic literature.

Slender Wheatgrass

Agropyron trachycaulum (Link) Malte var. *typicum* Fern. formerly *Agropyron pauciflorum.* A member of the genus which embraces the group commonly called the wheatgrasses. The use of *western ryegrass* is incorrect and therefore its use must be discouraged. Furthermore, the latter is suggestive of other genera as *Elymus* (Wild-rye) or *Lolium* (Rye-grass).

Tillering or *Stooling*

Synonymous. *Stooling* was first applied in horticulture and foresty to denote growth from stumps and basal parts of the plant. *Tillering* appeared in the literature later and was applied to secondary shoots in cereal crop plants. The latter seems to have been preferred by Percival.[2]

[1] Crafts, A. S. Selectivity of herbicides. Plant Physiol. 21 : 345-361. 1946.
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THE COMPOSITION AND CLASSIFICATION OF FOREST FLOORS AND RELATED SOIL PROFILES IN SASKATCHEWAN[1]

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A study of the forest floor is a branch of soil science which has received very little attention. Pedologists in proposing new systems of soil classification generally have been reluctant to deal with the forest humus layers. Joffe (6), as well as other workers, has pointed out the importance of the organic layers in the process of podzolization. It would therefore seem that the humus layers should be considered as part of the soil itself.

The term "forest floor" is defined as the accumulation of organic matter on the soil surface under forest cover (8). In terms of soil horizon designations this includes the A_{00} horizon which is referred to as the leaf litter layer (LL), and the A_0 horizon which may be further subdivided into the "fermentation" (F) and "humified" (H) layers. The F layer consists of the more or less decomposed forest litter, still recognizable as to origin. The H layer consists principally of organic matter, usually unrecognizable as to origin (5). Either F or H layers may be absent in some forest soils.

One important development in the field of forest floor studies has been the establishment of a system of nomenclature for the different types of forest floors occurring in northeastern United States (5). The above mentioned paper gives a complete review of former methods of nomenclature and directs attention to the variations in morphological features of the A_0 horizon which can easily be recognized in the field. The material presented in the above mentioned paper served as a guide in the classification of Saskatchewan forest floors.

Location and Extent

The forests of Saskatchewan, which have been classified by Halliday (4) as belonging to the boreal forest region, occupy about 100 million acres of the province (9) and of this acreage about 6.5 million acres are in forest reserves (12). The denser forests occur in the "gray" and "gray-black" transition soil zones of Saskatchewan which occupy about 31 million acres (9). (Figure 1.)

Vegetation

In the forest region of Saskatchewan the characteristic association is a mixture of aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) white spruce (*Picea glauca*), and white birch (*Betula papyrifera*). Jack

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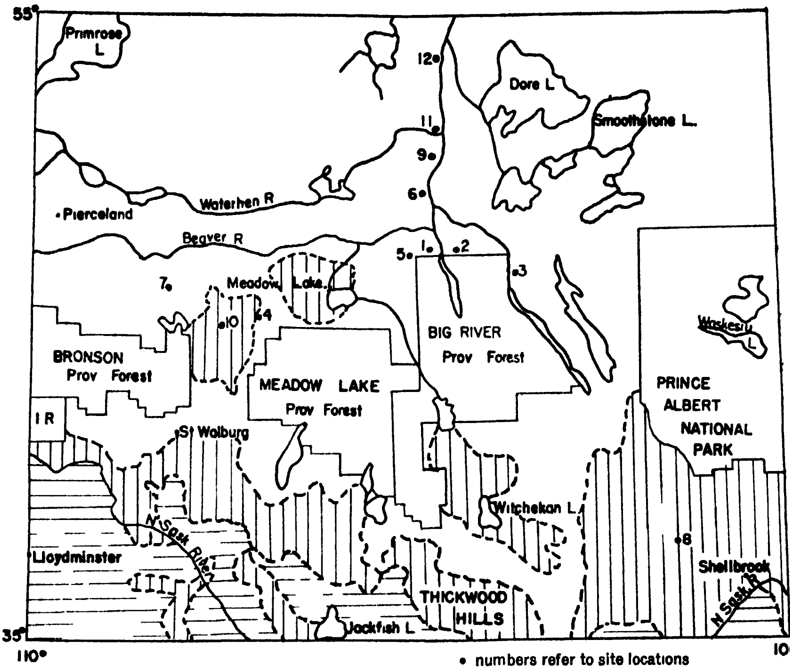
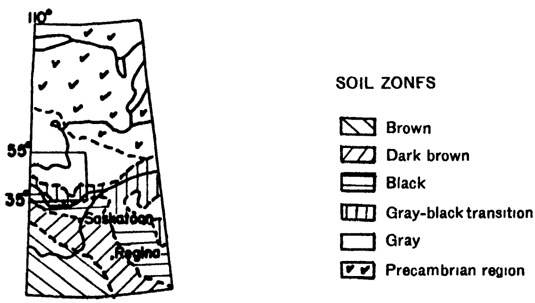


FIGURE 1 Sectional map showing soil zones and sample sites •
Additional data



Key map of Saskatchewan

pine (*Pinus banksiana*) associations tend to predominate on the coarse textured gravelly sandy areas. The depressional areas develop black spruce (*Picea glauca*) and tamarack-sphagnum bogs which are not, however, of any great depth Willows (*Salix sp.*) occur on alluvial deposits along streams and rivers.

Climate

The climate of the area concerned is classed as cool temperate with most of the precipitation falling during the short growing season. Meteorological data (10) indicate that the precipitation is less than 20 in. annually with most of it coming in the 5 summer months, May to September. Mean

monthly temperatures vary from about −10° F. in January to 60° F. in July. Winter temperatures lower than −65° F. and summer temperatures above 100° F. have been recorded.

SAMPLE SITES AND PROFILE DESCRIPTIONS

All of the sample sites were selected to represent, as nearly as possible, undisturbed old forest floors. The profile descriptions are given below and location of the sites is given in Figure 1.

SITE 1

Date of sampling:—August 7, 1944.
Forest floor type:—Granular mor.
Profile type:— Podzol.
Vegetation:— White spruce *Picea glauca* up to 18 in. d.b.h.,[1] twin flower Mitrewort, etc.
Topography:— Undulating.
Parent material:— Lacustrine.

A_{00}		Not sampled.
A_0	0 to 4 in.	H layer—Dusky reddish brown, somewhat matted fairly well decomposed organic material with pieces of roots easily discernable.
A_1	4 to 5 in.	Brownish gray mixture of mineral soil and well decomposed organic matter.
A_2	5 to 14 in.	Light brownish grey very fine sandy loam, platy structure crushing easily into powder.
B_1	14 to 18 in.	Rusty pale brown clay high in very fine sand, nutty structure breaking into coarse granules.
B_2	18 in. +	Brownish gray heavy clay, tough fragmental structure.

SITE 2

Date of sampling:—October 15, 1944.
Forest floor type:—Granular mor.
Profile type:— Rendzina-like.
Vegetation:— White spruce *Picea glauca* up to 24 in. d.b.h. sphagnum moss, Labrador tea, etc.
Topography:— Undulating.
Parent material:— Highly resorted boulder clay.

A_{00}	0 to $\frac{1}{4}$ in.	LL layer. Undecomposed needles, cones, and twigs.
A_0	$\frac{1}{4}$ to 5 in.	H layer. Pale brown granular slightly matted, fairly well decomposed organic material.
A_1	5 to 7 in.	Weak brown fine granular mixture of mineral soil and well decomposed organic matter. Slightly limy.
A_2	7 to 8 in.	Brownish gray moderately limy clay loam; cloddy nutty structure easily crushed to powder.
A_3	8 to 11 in.	Very light yellowish brown rust specked silty clay loam; moderately limy; platy structure easily crushed to powder.
B_1	11 to 24 in.	Light yellowish brown silty clay, flat topped columnar structure breaking into soft granules, faint laminated tendency.

[1] d.b.h.—diameter at breast height.

SITE 3

Date of sampling:—October 15, 1944.
Forest floor type:—Granular mor.
Profile type:— Podzol.
Vegetation:— White spruce *Picea glauca* up to 12 in. d.b.h. mixed with dead poplar (Populus sp.) up to 24 in. d.b.h., sphagnum, bunch berry, etc.
Topography:— Undulating.
Parent material:— Heavy lacustrine.

A_{00}	0 to ¼ in.	LL layer. Broken cones, needles, and twigs.
A_0	¼ to 3 in.	H layer. Dark brown granular fairly well decomposed organic material held together by considerable gray mold.
A_1	3 to 3½ in.	Dusky brown granular mixture of mineral soil and well decomposed organic matter.
A_2	3¼ to 10 in.	Light gray silty clay loam, with platy structure which crushes easily to fine granules and powder.
B_1	10 to 24 in.	Light brownish gray heavy clay, very tough nutty structure.
B_2	24 to 36 in.	Heavy clay, pale brown in colour, mottled with gray, extremely tough fragmental structure.

SITE 4

Date of sampling:—September 23, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Aspen *Populus tremuloides* up to 10 in. d.b.h., prairie rose, pea vine, grass, etc.
Topography:— Undulating.
Parent material:— Boulder clay.

A_{00}		Too thin to sample.
A_0	0 to ¼ in.	F layer. Dark brown slightly decomposed leaf litter and twigs.
	¼ to 2½ in.	H layer. Brownish black matted organic material fairly well decomposed.
A_1	2¼ to 4 in.	Dusky brown granular mixture of mineral soil and well decomposed organic matter.
A_2	4 to 8 in.	Light brownish gray loam, thick platy structure breaking to small nutty platy fragments.
B_1	8 to 16 in.	Light brownish gray clay, tough fragmental structure.

SITE 5

Date of sampling:—October 14, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Aspen *Populus tremuloides* up to 18 in. d.b.h., pea vine, prairie rose, golden rods, twin flower, strawberry, grass, etc.
Topography:— Very gently rolling.

Parent material:— Lacustrine.

A_{00}		LL layer. Undecomposed leaves and twigs.
A_0	0 to $\frac{1}{4}$ in.	F layer. Brownish black slightly decomposed leaves and twigs.
	$\frac{1}{4}$ to 2 in.	H layer. Dusky brown matted fairly well decomposed organic material.
A_2	2 to 8 in.	Very pale brown clay, platy to hard granular structure.
B_1	8 to 14 in.	Pale brown heavy clay, fairly tough fragmental to coarse granular structure.
B_2	14 to 22 in.	Yellowish light brown silty clay, fragmental structure.

SITE 6

Date of sampling:—October 14, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Paper birch *Betula papyrifera* up to 12 in. d.b.h. with occasional small alder (*Alnus incana*), marsh reed grass, twinflower, Labrador tea, blueberry, reindeer moss, etc.
Topography:— Undulating.
Parent material:— Lacustrine.

A_{00}		Too thin to sample.
A_0	0 to $\frac{1}{4}$ in.	F layer. Slightly decomposed leaves, twigs and grass.
	$\frac{1}{4}$ to $1\frac{1}{2}$ in.	H layer. Weak brown, very matted fairly well decomposed organic material.
A_1	$1\frac{1}{2}$ to $1\frac{3}{4}$ in.	Dusky brown mixture of mineral soil and well decomposed organic matter with quite a few rootlets.
A_2	$1\frac{3}{4}$ to 5 in.	Very pale brownish gray very fine sand, coarse granular structure crushing easily to fine powder.
B_1	5 to 15 in.	Light yellowish brown loamy very fine sand, soft cloddy structure crushing easily to powder.

SITE 7

Date of sampling:—October 14, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Balsam poplar *Populus tacamahacca* up to 24 in. d.b.h., prairie rose, snowberry, bunchberry, twinflower, etc.
Topography:— Undulating.
Parent material:— Alluvial.

A_{00}		LL layer. Undecomposed leaves and twigs.
A_0	0 to 4 in.	H layer. Dark brown matted well decomposed organic material.
A_2	4 to 24 in.	Very pale brown loamy very fine sand, faint platy structure crushing easily into fine granules and powder.
B_1	24 in. +	Light yellowish brown rusty very fine sandy loam faint cloddy structure crushing easily into medium granules.

SITE 8

Date of sampling:—October 16, 1944.
Forest floor type:—Dry mor.
Profile type:— Podzolized sand.
Vegetation:— Jack pine *Pinus Banksiana* up to 12 in. d.b.h., bear berry, moss cranberry, etc.
Topography:— Very gently rolling.
Parent material: Alluvial sand.

A_{00}		LL layer. Undecomposed needles, cones, and bark.
A_0	0 to ¼ in.	H layer. Weak brown well decomposed needles mixed with some grains of sand
A_2	¼ to 1 in.	Brownish gray medium sand held together by small root hairs.
B	1 to 2½ in.	Light yellowish brown sand, soft cloddy structure.
C	2½ in. +	Strong yellowish brown structureless sand.

SITE 9

Date of sampling.—September 9, 1944.
Forest floor type·—Dry mor.
Profile type:— Podzolized sand.
Vegetation.— Jack pine *Pinus Banksiana* up to 12 in. d b h., club moss, bear berry, moss cranberry, Laborador tea, etc.
Topography.— Very gently rolling.
Parent material:— Alluvial sand.

A_{00}		LL layer. Undecomposed needles, cones, and bark.
A_1	0 to ¼ in.	Well decomposed organic matter mixed with brownish gray structureless sand.
A_2	¼ to 2½ in.	Brownish gray fine sand held together with fine rootlets
B	2½ to 5 in.	Light yellowish brown fine sand, very faint cloddy structure.
C	5 in. +	Light yellowish brown structureless sand.

SITE 10

Date of sampling:—October 13, 1944.
Profile type:— Shallow peat on calcareous soil.
Vegetation:— Black spruce *Picea mariana* up to 15 in. d.b.h., Laborador tea, twinflower, Mitrewort, etc.
Topography.— Depressional.
Parent material:— Lacustrine

A_{00}		Undecomposed twigs, cones, and needles.
A_0	0 to ¾ in.	Layer 1. Slightly decomposed needles, dusky brown in colour.
	¾ to 5½ in.	Layer 2. Weak brown granular loosely matted fairly well decomposed organic material.
A	5½ to 12 in.	Black mineral soil very high in well decomposed organic matter, fine granular. Remains of charred wood present.
B	12 to 16 in.	Dusky brown clay, soft cloddy structure breaking down to fine granules.
C	16 to 24 in.	Light yellowish brown clay quite limy.

SITE 11

Date of sampling:—October 15, 1944.
Profile type:— Shallow peat on calcareous soil.
Vegetation:— Willow *Salix* sp., up to 9 in. d.b.h., nettles, ferns, raspberries, etc.
Topography:— Level.
Parent material:— Recent alluvial

A_0	0 to ¼ in.	Layer 1. Very slightly decomposed leaves.
	¼ to 3 in.	Layer 2. Dark brown quite loose well decomposed organic matter.
A	3 to 13 in.	Dusky brown mixture of mineral soil and very well decomposed organic matter. Cloddy structure crushing easily to fine granular structure.
G	13 to 25 in.	Rusty brownish gray silt loam, soft cloddy structure.
C	25 to 36 in.	Pale brown rust streaked silty clay.

SITE 12

Date of sampling:—October 15, 1944.
Profile type:— Sphagnum peat.
Vegetation:— Tamarack *Larix laricina* up to 6 in. d.b.h., sphagnum, Laborador tea, blueberry, etc.
Topography:— Depressional.

A_{00}		Undecomposed needles.
A_0	0 to 4 in.	Layer 1. Light olive brown raw sphagnum and some partially decomposed needles.
	4 to 8 in.	Layer 2. Light yellowish brown slightly decomposed sphagnum moss, very loose and spongy.
	8 to 10 in.	Layer 3. Weak brown well decomposed organic material permeated with rootlets and fairly compact.
C	10 to 30 in.	Very pale brown structureless sand.

DISCUSSION OF FOREST FLOORS

The forest floors of Saskatchewan belong to the mor group. This group is characterized by a layer of unincorporated organic material usually matted or compact or both, distinctly separable from the underlying mineral soil unless the latter has been blackened by washing in of organic matter. Three main types have been recognized in this group, namely, granular, matted, and dry mor.

The granular mor type occurs mainly under solid stands of white spruce. It is recognized by the absence of a well developed root mat in the H layer. A generalized description of this type is given below:—

(1) LL layer. Undecomposed needles, cones, and twigs. Very seldom exceeds ¼ in. in thickness.

(2) F layer. Usually absent.

(3) H layer. Granular, slightly matted, well decomposed organic matter. Varying shades of brown in colour. Has been found up to 5 in. in thickness but is more often around 3 in. thick under fairly heavy tree cover.

The matted mor type is found under the deciduous trees—aspen, balsam poplar, and birch. This type is characterized by a dense root mat holding the H lay together and is described as follows:—

(1) LL layer. A thin layer of undecomposed leaves and twigs.

(2) F layer. Slightly decomposed leaves and twigs with no evidence of matted or laminated structure. Usually dark brown in colour. This layer is quite thin, usually about $\frac{1}{4}$ in. thick, and may be absent.

(3) H layer. Fairly well decomposed organic matter. It is held together by a network of fine roots. This layer is usually thinner than the H layer of granular mor, and very seldom exceeds 3 in. in thickness.

The matted mor type may also be found under mixed aspen and white spruce forest cover, but here we find graduations in type from matted to granular mor depending on the relative numbers of each tree variety present.

The dry mor type is found under jack pine. Solid stands of jack pine in Saskatchewan occur principally on well drained sandy and gravelly soils which are very low in fertility. The combination of low fertility and excessive drainage seem to result in the development of a very thin forest floor, which is chiefly composed of litter consisting of undecomposed needles, cones, and bark. No F layer is present and the H layer is a very thin mat of well decomposed loose, structureless organic matter, quite often mixed with fine grains of sand. The classification of humus layers in northeastern United States made no provision for a forest floor of this type which belongs to the mor group. The name "dry" mor is suggested for this type of forest floor because of its very poor development; it appears rather dry and arid in comparison with other humus types encountered.

The combination of a short growing season and low annual rainfall prevailing in Saskatchewan forest areas results in a less dense tree cover, smaller leaves, and lighter leaf fall than is found in areas such as northeastern United States. This climatic factor is reflected in the development of thin humus layers, and in many instances no F layer is discernable.

Local variations in thickness of the forest floor depend on the nature of the mineral part of the soil—its texture, structure, drainage, and chemical composition, and on topography. Thinner organic layers are expected where the soil is lighter in texture, excessively drained, and lower in plant nutrients; they would also be expected on the crest of a hill.

The classification of forest floors as proposed by Heiberg and Chandler (5) was applied only to well-drained upland soils. However, it has been noticed that the organic layers developed under white spruce on a rendzina-like soil are quite similar in morphological features to those layers developed under white spruce on podzol soils. Further, chemical data presented in this paper will also show considerable similarity between the forest floors developed on a podzol and a rendzina-like soil type.

The humus layers under black spruce and willow cannot be classified with upland types, because these trees are confined primarily to swamps and poorly drained locations. It is interesting to note that we have an A_0 horizon under black spruce which consists of two layers—the upper layer is thin and slightly decomposed while the lower layer is thick, granular and

well decomposed being quite similar to the H layer under white spruce. These layers have been numbered for convenience in referring to the A_0 horizon. Two well developed humus layers were separated under willow. Layer 1 was quite thin and closely resembles the F layer of upland humus types while layer 2 had no noticeable structure, being quite loose and open.

In conducting this study, chemical analysis of forest floors, and peats and their related soil profiles have been carried out to determine whether or not:—

(i) similar forest floor types are similar in chemical composition;

(ii) differences in morphological features of forest floor types are reflected by differences in chemical composition;

(iii) the organic constituents of leaf litter from various tree species undergo somewhat similar changes during decomposition; and

(iv) to present data on chemical composition of forest and sphagnum peats in Saskatchewan.

ANALYTICAL DATA AND DISCUSSION

Methods

The pH was determined with a Coleman pH electrometer. Total nitrogen and loss-on-ignition were determined by standard analytical procedures, while the dry combustion method was used to determine total carbon. Procedures for proximate analysis, as outlined by Waksman and Stevens (13, 14) were used to determine organic constituents. The method proposed by Blish and Sandstedt (2) was adopted for determining percentage of hemicellulose and cellulose.

Table 1 gives the pH, loss-on-ignition, nitrogen, organic carbon, and C/N ratios for the forest humus layers and peats and their related soil profiles.

TABLE 1.—ANALYTICAL DATA FOR PROFILES ON SITES NO. 1 TO NO. 12. RESULTS EXPRESSED ON OVEN DRY BASIS

Horizon or layer	Depth	pH	Loss-on-ignition	Nitrogen	Carbon	C/N
			%	%	%	
Site 1. Granular mor. White spruce on podzol.						
H	0 to 4 in.	5.73	90.86	2 03	49 60	24
A_1	4 to 5 in.	5.10	9.29	0 198	4 14	21
A_2	5 to 14 in.	5 30	1.50	0.066	0.35	5
B_1	14 to 18 in.	5 10	2.45	0 011	0.44	40
B_2	18 in. +	6.12	3 90	0.031	0.56	18
Site 2. Granular mor. White spruce on rendzina-like soil profile.						
LL	0 to ¼ in.	5.60	90.64	1.17	47.60	41
H	¼ to 5 in.	5.05	90 24	1.53	50 70	33
A_1	5 to 7 in.	7.80	39.99	1.02	22.37	22
A_2	7 to 8 in.	8.00	13.01	0.41	7 42	18
A_3	8 to 11 in.	8.10	1.32	0.018	0 43	24
B_1	11 to 24 in.	7.72	1.38	0.014	0.25	18

TABLE 1 —ANALYTICAL DATA FOR PROFILES ON SITES NO 1 TO NO 12
RESULTS EXPRESSED ON OVEN DRY BASIS—*Continued*

Horizon or layer	Depth	pH	Loss on ignition	Nitrogen	Carbon	C/N
			%	%	%	
Site 3 Granular mor White spruce on podzol						
LL	0 to ¼ in	5 52	94 13	1 27	49 60	39
H	¼ to 3 in	4 70	84 03	2 11	47 75	23
A_1	3 to 3½ in	5 52	32 40	0 82	16 76	21
A_2	3½ to 10 in	5 55	1 69	0 020	0 54	27
B_1	10 to 24 in	4 24	4 94	0 046	0 73	16
B_2	24 to 36 in	4 31	1 54	0 010	0 27	27
Site 4 Matted mor Aspen on podzol						
F	0 to ¼ in	5 76	77 94	1 95	43 40	22
H	¼ to 2½ in	6 00	69 00	2 09	38 50	19
A_1	2½ to 4 in	5 40	10 24	0 356	5 96	17
A_2	4 to 8 in	5 22	1 47	0 050	0 51	10
B_1	8 to 16 in	5 65	2 62	0 044	0 64	14
Site 5 Matted mor Aspen on podzol						
L L	—	5 59	83 95	1 27	43 20	34
F	0 to ¼ in	6 20	79 61	1 96	43 80	22
H	¼ to 2 in	5 70	56 80	1 61	31 30	19
A_2	2 to 8 in	4 85	2 07	0 046	0 65	15
B_1	8 to 14 in	5 00	3 37	0 047	0 63	13
B_2	14 to 22 in	4 95	1 99	0 029	0 40	14
Site 6 Matted mor Birch on podzol						
F	0 to ¼ in	5 90	89 75	2 34	42 40	18
H	¼ to 1½ in	5 50	82 74	2 34	42 65	18
A	1½ to 1¾ in	4 60	38 65	1 24	21 45	17
A_2	1¾ to 5 in	4 40	2 15	0 066	0 98	15
B_1	5 to 15 in	5 40	0 86	0 020	0 34	17
Site 7 Matted mor Balsam poplar on podzol						
L L		5 70	90 17	1 63	40 40	25
H	0 to 4 in	5 80	81 64	2 30	39 60	17
A_2	4 to 24 in	5 70	0 85	0 009	0 48	50
B_1	24 in +	5 46	1 64	0 007	0 39	56
Site 8 Dry mor Jack pine on podzolized sand						
LL	—	4 50	95 08	0 91	41 40	46
H	0 to ¼ in	4 71	74 62	1 27	37 10	29
A_2	¼ to 1 in	5 10	4 71	0 080	2 55	33
B	1 to 2½ in	5 30	1 21	0 027	1 33	49
C	2½ in +	6 12	0 55	0 010	0 11	11
Site 9 Dry mor Jack pine on podzolized sand						
LL		4 30	88 63	0 99	41 70	42
A_1	0 to ¼ in	4 70	12 35	0 222	6 86	31
A_2	¼ to 2½ in	5 86	2 45	0 048	1 84	38
B	2½ to 5 in	6 00	1 03	0 007	0 68	97
C	5 in +	5 48	0 60	0 010	0 25	25

TABLE 1.—ANALYTICAL DATA FOR PROFILES ON SITES NO. 1 TO NO. 12. RESULTS EXPRESSED ON OVEN DRY BASIS—*Concluded*

Horizon or layer	Depth	pH	Loss-on-ignition	Nitrogen	Carbon	C/N
			%	%	%	
Site 10. Shallow peat. Black spruce on lacustrine clay.						
LL	—	5 36	89 78	1 19	39 70	33
1	0 to ¾ in.	4 80	82 60	1 59	38 10	24
2	¾ to 5½ in.	5 35	85 96	1 68	41 20	24
A	5½ to 12 in.	7 29	36 46	1 27	29 60	24
B	12 to 16 in.	7 62	5 80	0 256	3 37	13
C	16 to 24 in	7.73	1 97	0 035	0 43	12
Site 11. Shallow peat. Willow on alluvial silty clay.						
1	0 to ¼ in.	6 44	89 30	2 10	39 30	19
2	¼ to 3 in.	7 56	76 58	2 46	39 10	16
A	3 to 13 in.	6 95	31 30	0 77	12 30	16
B	13 to 25 in.	8 08	16 60	0 54	5 08	9
C	25 to 36 in.	8 00	6 70	0 206	1 61	7
Site 12. Sphagnum peat. Tamarack.						
LL	—	4 64	95 32	0 76	43 60	52
1	0 to 4 in	3 95	94 53	1 05	41 26	39
2	4 to 8 in	4 75	89 25	1 32	41 30	31
3	8 to 10 in.	4 12	78 61	1 72	40 25	23
C	10 to 30 in.	5.25	0 86	0 03	0 35	12

pH Values

The granular and dry mor types are more acid than matted mor. The pH of granular mor decreases with decomposition of leaf litter. There is an increase in pH with decomposition of leaf litter in both dry mor and matted mor, but the H layer of matted mor is more acid than the F layer. The litter and H layer of granular mor on a rendzina-like soil (pH 8) are the same as the organic layers of granular mor on podzol soils. Organic layers of dry mor were more acid than the underlying soil horizons while the matted mor humus layers were less acid than the underlying soil horizons. Shallow peat, developed under black spruce on a calcareous soil, was quite acid while shallow peat developed under willow on a calcareous soil was close to neutral in reaction. The tamarack-sphagnum peat layers were very acid.

Loss-on-Ignition (Ash Content)

Loss-on-ignition can be used as a measure of total organic matter in forest floors and also gives the percentage of ash present. Litter under deciduous trees is higher in mineral content than litter under conifers. Humus layers of matted and dry mor are higher in mineral content than the corresponding layers in granular mor. The high ash content of the H layers in granular and dry mor may be due partly to mixing with the underlying mineral soil. There was evidence of sand particles mixed in with the H layer in dry mor.

The Nitrogen Content

Table 1 shows the total nitrogen content for the forest floor layers and peats and their related soil horizons. Litter developed under jack pine and tamarack was considerably lower in total nitrogen than litter from the other tree varieties. The humus layers were higher in nitrogen than the leaf litter from which these layers were derived. Humus layers in the dry mor type were noticeably lower in total nitrogen than humus layers in granular or matted mor. Nitrogen content of the peats also increased with the depth of the peaty layers.

The distribution of nitrogen fractions (water soluble, HCl hydrolyzable, and "lignin-nitrogen") in the 3 mor forest floor types was also determined and representatives of each type with their fractional analysis are shown in Table 2. The amount of nitrogen recovered in the portion hydrolyzed by H_2SO_4 was negligible, the highest recovery being 0.03% with no recovery for most of the samples.

TABLE 2.—DISTRIBUTION OF THE NITROGEN FRACTIONS OF REPRESENTATIVE MOR FOREST FLOORS

Type of forest floor	Tree variety and site no.	Layer	Water soluble nitrogen	HCl hydrolyzable nitrogen		Lignin nitrogen	Total % nitrogen	Nitrogen unaccounted for
				Nonamide	Amide			
Granular mor	W. spruce 3	LL	0 13	0 21	0 07	0 97	1 27	−0 11
Granular mor	W. spruce 3	H	0 00	0 47	0 14	1.62	2 11	−0 03
Dry mor	Jackpine 8	LL	0 00	0 01	0 05	0 83	0 91	0 03
Dry mor	Jackpine 8	H	0 03	0 02	0 17	1.22	1 27	−0 05
Fibrous mor	Aspen 5	LL	0.00	0 00	0 07	1 01	1 27	0 19
Fibrous mor	Aspen 5	F	0 00	0 02	0 11	1 88	1 96	−0 05
Fibrous mor	Aspen 5	H	0 00	0 00	0 14	1.39	1.61	0 08

With the exception of litter under white spruce, there was little or no water soluble nitrogen present. In fibrous and dry mor almost all of the nitrogen hydrolyzed by dilute HCl was of an amide (NH_3) nature. The granular mor had practically the same amount of amide nitrogen and, in addition, had a fair amount of non-amide nitrogen in the dilute HCl fraction. The % of amide nitrogen increased with degree of decomposition in all 3 mor types. Almost all of the nitrogen in fibrous and dry mor, and over 75% of the nitrogen in granular mor, remained insoluble in hot mineral acids and was recovered in the complex lignin-nitrogen fraction.

The Organic Carbon Content

No inorganic carbonates were found in the forest floor layers, and so all of the carbon present was in the organic form. The interest in organic carbon centers primarily around the more or less definite ratios between carbon and nitrogen, and carbon and organic matter in the soil.

The C/N Ratios

From Table 1 it is seen that C/N ratios for leaf litter varied from 25 for balsam poplar to 52 for tamarack, with an average of 39. Conifer litter

had a higher C/N value than the litter of deciduous trees. The C/N ratios for humus layers of granular and dry mor averaged about 27 and were higher than the C/N ratios for humus layers of matted mor with an average value of 19. The shallow peat layers had a C/N ratio close to 20 while this ratio was wider for sphagnum peat. The average C/N ratio for all podzol samples was 22 which is very close to the ratios found by Anderson and Byers (1).

The Factor for Calculating Total Organic Matter

Loss-on-ignition data from organic materials such as peat soils and organic horizons of forest soils are very close to an exact measure of total organic matter (7). Table 3 gives factors to convert organic carbon percentages to total organic matter percentages. These factors were obtained by dividing loss-on-ignition values by the % of organic carbon in the sample.

TABLE 3.—CONVERSION FACTORS FOR CALCULATING PERCENTAGE OF ORGANIC MATTER FROM A KNOWLEDGE OF PERCENTAGE ORGANIC CARBON IN ORGANIC MATERIALS

Mor type	Layers		
	LL	F	H
Dry mor	2 20	—	2 01
Granular mor	1.90	-	1 79
Matted mor	2.08	1.93	1.90
Average	2 06	1.93	1 87

The average values obtained in Saskatchewan are slightly higher than those obtained by other workers (3, 7, 11, 18). The factors for dry mor are considerably higher than for any other mor type, being close to the factor of 2.14 which was obtained for peats in Saskatchewan. The factors for granular mor are very close to factors found by Lunt (7).

DISCUSSION OF THE ORGANIC CONSTITUENTS

Since the primary interest is in the composition of organic matter, the % of the various fractions separated will be discussed as a % of the organic matter rather than as a % of the total sample. Loss-on-ignition values for leaf litter, humus layers, and peats is regarded as being the most reliable approximation to organic matter content, so values given in the following discussions will be on an oven-dry, ash-free basis. The organic matter of the A_1 horizons is calculated using the factor 1.724. Recoveries of organic constituents for 30 samples analyzed varied from 87 66% to 102.22% with an average recovery of 95.79%. These results compare favourably with results reported by Waksman and Stevens (13) which accounted for 85 to 98% of the constituents. All values given will be also calculated on the basis of 100% recovery to make comparisons between samples somewhat easier. Table 4 presents the % of organic constituents in organic matter of forest floors, peats, and A_1 horizons.

TABLE 4.—PERCENTAGE OF ORGANIC CONSTITUENTS

Layer or horizon	Ether-soluble	Alcohol-soluble	Water-soluble	Hemi-celluloses	Cellulose	Lignin	Nitrogen complexes ($N_2 \times 6.25$)
	%	%	%	%	%	%	%
Site 1. Granular mor under white spruce on podzol.							
H	1.65	5.05	5.81	22.50	8.32	41.57	15.10
Site 2. Granular mor under white spruce on rendzina-like profile.							
LL	3.92	4.11	9.03	21.16	14.30	39.02	8.46
H	1.81	3.10	6.21	23.65	9.29	44.82	11.12
A_1	.81	1.07	3.72	16.63	3.81	58.90	15.16
Site 3. Granular mor under white spruce on podzol.							
LL	11.37	4.57	5.58	22.95	14.10	32.86	8.57
H	3.57	4.29	7.17	23.58	8.66	36.22	16.51
A_1	.85	1.60	4.88	22.61	5.49	49.26	15.43
Site 4. Matted mor under aspen on podzol.							
F	4.47	4.64	6.03	22.85	9.30	35.77	16.99
H	2.33	3.16	7.40	19.98	7.92	38.76	20.45
Ste 5. Matted mor under aspen on podzol.							
LL	6.55	8.75	7.57	23.55	16.70	26.85	9.83
F	4.33	4.73	5.59	23.00	10.38	35.12	16.85
H	2.29	4.22	4.86	22.59	10.17	37.92	17.91
Site 6. Matted mor under birch on podzol.							
F	4.44	4.31	8.37	25.03	12.50	27.65	17.50
H	2.46	5.38	7.60	22.84	9.45	32.72	19.55
A_1	2.76	3.66	4.88	16.28	5.66	47.76	19.00
Site 7. Matted mor under balsam poplar on podzol.							
LL	7.83	4.53	8.83	20.90	14.76	30.80	12.35
H	2.34	3.75	8.96	20.32	9.16	36.07	19.40
Site 8. Dry mor under jack pine on podzolized sand.							
LL	6.69	4.94	6.80	23.95	22.12	29.53	5.97
H	3.63	3.97	8.40	21.41	15.53	36.01	11.05
Site 9. Dry mor under jack pine on podzolized sand.							
LL	5.63	4.35	8.85	23.45	17.13	33.49	7.10
Site 10. Shallow peat under black spruce on calcareous soil.							
LL	6.01	4.56	6.21	24.95	19.35	30.31	8.61
1	4.81	5.42	9.78	20.78	14.09	32.20	13.02
2	1.53	2.80	8.14	20.80	7.89	45.92	12.92

TABLE 4.—PERCENTAGE OF ORGANIC CONSTITUENTS—*Continued*

Layer or horizon	Ether-soluble	Alcohol-soluble	Water-soluble	Hemi-celluloses	Cellulose	Lignin	Nitrogen complexes ($N_2 \times 6.25$)
Site 11. Shallow peat under willow on calcareous soil.							
1	3.89	6.05	9.12	20.82	10.93	32.19	17.00
2	1.31	2.34	6.40	18.32	8.96	40.81	21.86
A_1	.11	.71	4.43	19.40	4.16	53.94	17.25
Site 12. Sphagnum-peat with tamarack.							
LL	9.86	13.71	16.06	20.31	11.76	22.44	5.26
1	1.90	5.54	12.28	41.76	16.36	15.34	6.82
2	2.09	2.86	5.68	47.25	15.60	16.94	9.86
3	2.15	3.03	7.28	33.03	9.63	29.77	15.11

The Ether-Soluble Materials (Fats and Waxes)

The amounts of ether-soluble materials present in matted and dry mor are quite similar. These materials are also neutral to litmus. Granular mor is quite variable in ether-soluble material content and these materials are slightly acid to litmus. The shallow peats are somewhat similar to the forest floors in amount of ether-soluble materials present. The waxes and fats in sphagnum peat must be of a nature resistant to decomposition by micro-organisms, for on referring to Table 4, we see that these materials which are soluble in ether increase slightly whereas they decrease fairly rapidly down the profile in forest floors and shallow peats.

The Alcohol-Soluble Materials

The alcohol-soluble materials were brown in colour and slightly acid to litmus. The % of these materials in all mor types is about the same. In all forest floor types, excepting matted mor under birch, the alcohol-soluble materials decrease in amount with decomposition. This is true also for the shallow peats. The alcohol-soluble substances in sphagnum peat decrease during the initial stages of decomposition, but seem to resist further breakdown. This would indicate that some of the materials are easily decomposed while others are quite resistant to attack by micro-organisms. The leaf litter of tamarack and aspen is considerably higher in alcohol-soluble materials than that of any other tree varieties. Tamarack needles are particularly high in these materials being slightly higher than needles of *Pinus strobus* (white pine) reported by Waksman (13).

The Water-Soluble Fraction

There seems to be little difference between the forest floor types and shallow peats with regard to the amount of water-soluble materials present. In sphagnum peat the water-soluble substances decreased markedly from layer 1 to layer 2, but there was an increase in the third layer.

The Hemicellulose Fraction

The hemicelluloses of plant residues are made up chiefly of pentosans, hexosans and polyuronides. Pentosans decompose fairly slowly (15, 16), and of the two most common hexosans, mannin decomposes quite readily while galactin is very resistant to decomposition. Polyuronides increase on decomposition of plant remains because of extensive synthesis by micro-organisms. An understanding of these facts is necessary to interpret the data in Table 4.

In granular mor the hemicellulose content increases with decomposition, presumably because of a high proportion of the resistant hexosan galactin or because of extensive synthesis of polyuronides by the type of micro-organisms present. In the other forest floor types, the amount of hemicelluloses decreases with decomposition probably because of a higher % of pentosans and the hexosan mannin. Jack pine litter is higher in hemicellulose than the litter of any of the other upland forest trees. The hemicellulose content of black spruce and tamarack litter, and of the shallow peats is not unlike that of the upland forest floors. Sphagnum peat contains over twice as much hemicellulose as the other peats. Almost half of the sphagnum peat in the upper layers consists of hemicelluloses. These hemicelluloses seem to be somewhat resistant to decomposition as they increase in layer 2, but they do decrease in layer 3. It is probable that layer 3 did not originate directly from the sphagnum but rather from earlier plants (cat-tails, sedges, etc.), which started the bog formation. We would therefore expect the composition of this layer to be different from that of the first two layers.

The Cellulose Fraction

Cellulose, being one of the main energy sources for micro-organisms, is broken down rapidly during decomposition of leaf litter. There is a decrease of 30 to 40% in cellulose from the leaf litter to the H layer in all the forest floor types and shallow peats. There is a slight decrease in cellulose content of sphagnum peat from layer 1 to layer 2, and then a sharp decrease from layer 2 to layer 3, again suggesting the possibility of some different origin for layer 3.

The Lignin Fraction

The lignin content in granular mor increased about 12% from the LL to the H layer. In dry mor, the lignin increased about 20% from the LL to the H layer while in matted mor the lignin content increased almost 30%. For matted mor types, where F layers were present, the lignin content increased about 10% from the F to the H layers. In shallow peat, there was quite a rapid increase in lignin content with increasing depth. In sphagnum peat we find very little increase from layer 1 to layer 2 and then a very large increase in layer 3 which again indicates that layer 3 is of different origin to layers 1 and 2.

The Nitrogenous Complexes

If these complexes are assumed to be somewhat similar in composition to the proteins of plant and animal residues, the factor of 6.25 can be used to convert % nitrogen to % of nitrogenous complexes. Since nitrogen

content of the various samples was discussed previously there is only one point left to discuss here. It has been demonstrated by Waksman (17) that protein and lignin form a resistant complex which possesses the various chemical, physico-chemical, and biological characteristics of soil humus so it was thought that possibly there would be some relation between the amount of lignin and nitrogen present in the more highly decomposed H layers. Lignin and nitrogen content do increase as the litter is decomposed, but they do not reach a constant ratio for the humus layers studied here.

CHANGES IN ORGANIC CONSTITUENTS DURING DECOMPOSITION OF FOREST FLOORS

If the soil humus in all soils is made up of similar organic complexes, then the final decomposition products of leaf litter should be somewhat similar in composition. In an effort to see if this occurs, the organic matter of the humus layers and A_1 horizons of 4 widely varying forest and soil types was analysed. The types chosen for this study were granular mor on heavy textured podzol (site 3) and rendzina-like (site 2) soil types, matted mor on a podzol (site 6) soil and shallow peat (site 11) on a medium textured calcareous soil. The data is presented in Table 4.

The % of ether-soluble materials in the leaf litter and F layers varied considerably but in the A_1 horizon for 3 sites the % of these materials is almost the same. For all sites, the ether-soluble materials decreased down through the profile and seem to be still on the decrease in the A_1 horizon.

For the alcohol and water soluble materials, a somewhat similar condition exists. The content of these materials in the LL, F, and H layers varies considerably. In some instances, we find an increase in these materials with increasing depth of the forest floor. However, in all sites the alcohol and water-soluble materials decrease quite noticeably when we reach the A_1 horizon. This decrease is somewhat less in the podzol soils but the evidence tends to show that these materials are still decreasing in the A_1 horizon.

The cellulose content of these widely varying forest and soil types is very much the same and it is still on the decrease in the A_1 horizon, but with hemicelluloses widely varying results occur, as can be seen from Table 4. The only explanation to account for this is the fact that hemicelluloses consist of compounds differing in their chemical composition and resistance to decomposition. Because of the varying soil conditions, we may have conditions existing in one site which favour the decomposition of hemicelluloses by micro-organisms, whereas in another site conditions may prevail which favour the synthesis of hemicelluloses.

It has been shown earlier that nitrogenous complexes increase with decomposition of leaf litter in the forest floor. In the A_1 horizon we note that for some sites there is a decrease in % nitrogen in the organic matter. A point worthy of mention is that in general the nitrogen content of the organic matter seems to be going towards a constant value giving a ratio of C/N varying between 17 5 for willow to 26.5 for white spruce (site 3) with an average C/N ratio of 21.5.

The most noticeable change, as decomposition of organic materials in forest floors proceeds, is the increase in lignin content. There is a very marked increase in lignin from the H layer to the A_1 horizon. This increase

seems to be much greater here than results obtained by Shewan (11) and Waksman (18) and supports the theory that lignin is one of the "mother" substances of soil humus.

SUMMARY

Investigations concerned with the classification of forest floors in Saskatchewan have been carried out and the following observations have been made:—(1) A lighter leaf fall and thinner organic mat development is observed in Saskatchewan forests than in forests of northeastern United States. (2) The forest floors of Saskatchewan belong to the mor group. Three mor types were encountered; namely, granular, matted, and dry mor. The latter occurred under jack pine. The name "dry" mor has been suggested due to the very thin nature of this forest floor type and the existing classifications do not include a type similar to this.

Chemical analysis of forest floors in Saskatchewan reveals that:—(1) The granular and dry mor types are more acid than matted mor. (2) Humus layers of matted and dry mor are higher in mineral content than the corresponding layers in granular mor. (3) Litter under deciduous trees is higher in mineral content than litter under conifers. (4) Humus layers in dry mor are lower in total nitrogen than humus layers in granular or matted mor. (5) Almost all of the nitrogen in matted and dry mor was recovered in the resistant lignin fraction but in granular mor about 25% of the nitrogen was hydrolyzed by dilute acid and boiling water. (6) The C/N ratios for humus layers of granular and dry mor are higher than the C/N ratios for humus layers of matted mor (7) The factor to calculate % of organic matter from % of organic carbon is highest for dry mor and lowest for granular mor. (8) No consistent differences were noted between different forest floor types as regards amount of ether-, alcohol-, and water-soluble materials. The ether-soluble materials decrease fairly rapidly as the leaf litter is decomposed and these materials in granular mor are slightly acid to litmus. (9) For granular mor hemicelluloses increase with decomposition of the leaf litter whereas this fraction decreases with decomposition of the litter of other mor types. (10) For all forest types there is a rapid decrease in cellulose content with decomposition of the leaf litter. (11) There is a steady increase in lignin content of the organic matter with decomposition of leaf litter.

Shallow peats are quite similar to forest floors in chemical composition. Chemical analysis of sphagnum peat shows a very high hemicellulose content.

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MOISTURE RELATIONSHIPS OF THE WHEAT STEM SAWFLY (*CEPHUS CINCTUS* NORT.)

I. SOME EFFECTS OF DESICCATION[1]

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A frequently repeated concept of insect control is that the control measures are likely to be most successful if applied at the time when the species is most susceptible. In the case of the wheat stem sawfly (*Cephus cinctus* Nort.) one means of cultural control which has met with some measure of success is shallow tillage. The object of this operation is to loosen the wheat stubble and deposit it on the soil surface where it is more exposed to desiccation and high temperatures. The experiments reported here are the result of an attempt to find at which stage or at what time the insect is most susceptible to these conditions.

Shortly before the wheat is ready to harvest, the larva girdles the inside of the wheat stem, approximately at the soil surface. The stem, being weakened at this point, breaks off and falls, leaving a short stubble, or "stub," into which the larva has meanwhile retired, plugged the open end with frass, and lined with the translucent cocoon. The species spends about 10 months out of each year in the stub. As most stubs are 1 to 2 in. in length, the larvae can move up and down in response to temperature changes, thus escaping intense soil surface heat or taking advantage of warm sunshine at a time when the soil is still cold.

Larvae are in a state of diapause in the fall, but during the fall and winter this is gradually eliminated, and by spring they are ready for further morphological development. They change first to prepupae, then to unpigmented pupae which gradually become coloured, and finally to adults, all inside the stubs. The adults may leave the stubs at once or remain in them for some time, depending on climatic conditions (Manson 1934).

MATERIALS AND METHODS

Constant temperatures were maintained in cabinets with an accuracy of approximately ± 1.0° C. Constant humidities were obtained by the use of sulphuric acid and water mixtures in glass containers of 1 to 8 quart capacity.

When specimens were exposed while still in the stubs, the latter were stripped clean of loose dirt and leaves and the dried roots were clipped off. They were then exposed in loosely packed lots of 30 to 60 in screen-wire cups.

The moisture content of a sample was considered equivalent to the weight lost in an electric oven at 95° to 100° C. in 24 hours, at which time the dry weight had reached a constant minimum.

Stubs were obtained fresh from the field in the spring and fall. For winter work stubs were collected in the fall and stored in a root cellar until needed.

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EXPERIMENTAL RESULTS

Naked Larvae at 30° C.

Initial tests were made at 30° C. (86° F.) and relative humidities of 0 to 50%. The larvae, which were in a state of diapause, were removed from their stubs and cocoons so that they could be observed and weighed regularly. They were exposed in open 5 by 40 mm. vials, a procedure that was later discontinued as the vials were considered too long for adequate ventilation. Nevertheless, these tests are comparable with each other, and the results are presented graphically in Figure 1. It will be seen that under the conditions of the experiment all larvae lost weight rapidly at first but more slowly after about 10 days. As expected, larvae lost weight more quickly as the relative humidity decreased. Mortality was negligible until larvae had lost at least 40% of their initial weight, after which time they quickly succumbed. For this reason, the curves in Figure 1 are carried only to an average 40% weight loss. Up to this point fewer than 10% of the specimens died, and virtually all of these had already lost over 40% of their initial weight.

Although larvae lost weight readily under these temperature and moisture conditions, they survived for a surprisingly long time when it is considered that they were removed from the protection of their cocoons and stubs. If they had been exposed in their natural state, it would have taken considerably longer to produce any mortality. It appears certain that a temperature of 30° C., in itself, has no lethal effect on sawfly larvae in diapause. The larvae definitely died of desiccation and then only after losing over 40% of their initial weight.

Naked Larvae at 35° C.

A series of tests similar to those at 30° C. was run at 35° C. Except that the higher temperature resulted in a correspondingly faster rate of desiccation, the results were practically the same. The mortality and progressive weight loss at 7 relative humidities from 0 to 60% are listed in Table 1. As at 30° C., it is seen that the larvae lost weight faster and died sooner as the relative humidity decreased. Again, it seems unlikely that temperature alone had any lethal effect, except indirectly through its role in desiccation.

While Table 1 seems to indicate that some larvae died before losing 40% of their initial weight, this is not actually the case even at 60% R. H., as the values listed are averages based on the weight loss of survivors only. Table 2 shows that the weight loss at death averaged considerably more than 40%. These values, especially those for 0% R. H., are maxima, since the larvae inevitably lost some weight between the actual time of death and the time of weighing, a period of up to 48 hours. For all practical purposes, larvae may be considered near death from desiccation after losing 40% of their original weight. Actually, such factors as initial moisture content and the nutritional and physiological state of the specimens account for variation in the data.

Table 2 also lists the average longevity of the test larvae, which, as in the similar tests at 30° C., were exposed naked in 5 × 40 mm. open vials. The longevity alone shows that mortality is due to desiccation, and not

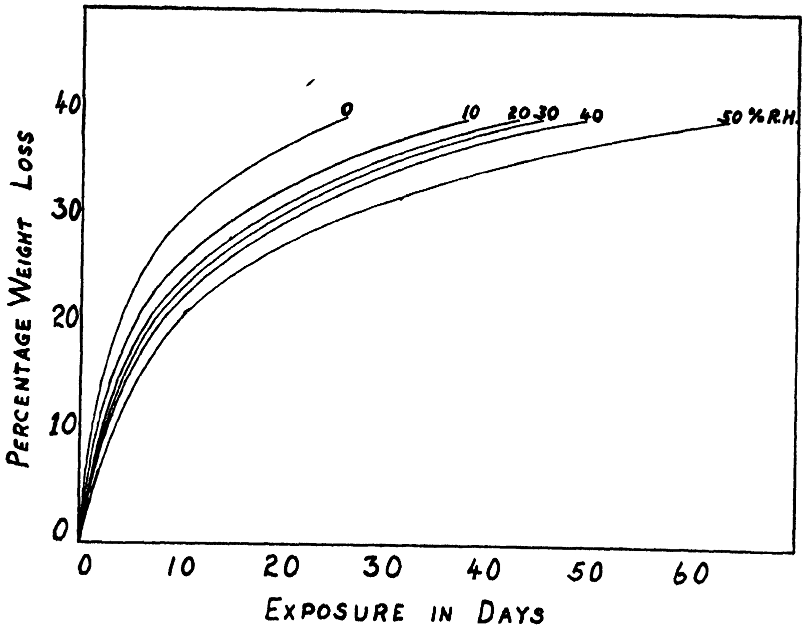

Figure 1

high temperature. Desiccation at any particular temperature and humidity, or at a certain vapour pressure deficit, is a function of time. That time also had no effect in itself is also shown in Table 2, where the values for weight loss, dry matter content, and moisture content, are virtually constant throughout the relative humidity range from 0 to 60% R. H (allowance being made in the extreme case at 0% R. H. for weight loss occurring after death but before weighing)

Naked Larvae at 40° C.

It has already been seen that mortality of naked *Cephus cinctus* larvae at 30° C. (0 to 50% R. H.) and at 35° C. (0 to 60% R. H.) resulted entirely from desiccation. At 40° C. (104° F) the same conclusion was reached for relative humidities up to 80% In this series, larvae were exposed in a more open type of container, consisting of sealing-wax trays with moulded depressions to keep the larvae isolated. At 0% and 10% R. H. the naked larvae dried, died, and continued to dry out so fast that accurate weighing was impossible. Approximate data were obtained for relative humidities of 20% and 40% to 80%.

The longevity was cut considerably by the 5° C. rise in temperature and the more open exposure Nevertheless, in this short time the weight loss was at least as great as during the longer exposures at 30° and 35° C. At 20 to 60% R. H. the weight loss values are undoubtedly too high, because of drying after death but before weighing (in this experiment, less than 24 hours). The values at 70 and 80% R H. are considered approximately

correct. The same conclusion is therefore drawn, as at 30° and 35° C., that death is due to desiccation, and occurs only after 40% of the original weight has been lost.

EFFECTS OF DESICCATION ON NAKED LARVAE

The experiments thus far reported have led to the conclusion that mortality of naked *Cephus cinctus* larvae under the conditions described is caused by desiccation. While the point at which the loss of moisture becomes fatal varies among individuals as a result of their previous history, it is certainly not far away when 40% of the initial weight has been lost. This situation held regardless of humidity within the limits used. Ludwig (1937) found that with Japanese beetle larvae, prepupae and pupae, death occurred at approximately the same water content, regardless of the rate of desiccation. In each case, water loss appears to be the limiting factor in survival. Whether larvae can closely approach lethal desiccation and yet recover when supplied with contact moisture is the subject of another paper.

The composition of material lost during desiccation is of some interest. It is predominantly water, but there is also a very appreciable loss of dry matter. The latter, of course, is not lost as such but as products of katabolism, principally water and carbon dioxide. This metabolic water is probably available to certain tissues and thus of some assistance in delaying fatal desiccation. Even in diapause, sawfly larvae do a considerable amount of "squirming" so that there is muscular activity as well as metabolic activity, though the latter is probably at a low level compared with actively developing forms.

Table 4 lists the averaged losses of total weight, water and dry matter of the specimens reported in Table 2, with the exception of those held at 0% R. H.

Values for initial moisture and dry matter contents are estimated, as it was of course impossible to obtain them from the actual specimens being desiccated. On the basis of larvae of similar stock, it was estimated that their moisture content averaged close to 54%, and this is the value used in Table 4.

Larvae lost an average of 46% of their weight before death. In doing so, their moisture content decreased by 61% and their dry matter content by 35%, resulting in a final moisture content of 38.5% and a final dry matter content of 61.5%. Thus, during desiccation the moisture content decreases in amount and in terms of percentage of body weight, whereas dry matter decreases in amount but increases in terms of percentage of body weight. This reversal of relative proportions of moisture and dry matter calls for care in the interpretation of data dealing with them. A mere statement of the percentage of moisture or dry matter may be adequate in some cases, particularly if the experimental material is carefully selected for uniformity. There are, however, many possibilities which are easily misinterpreted. An insect may lose both moisture and dry matter in such proportion as to retain its original percentage moisture content or dry

TABLE 1 —MORTALITY AND PROGRESSIVE WEIGHT LOSS (OF SURVIVORS) IN GROUPS OF 10 LARVAE EXPOSED TO 35° C AND RELATIVE HUMIDITIES OF 0% TO 60%

Exposure	0% R H		10% R H		20% R H		30% R H		40% R H		50% R H		60% R H	
	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss
Days		%		%		%		%		%		%		%
2	2	35.9	0	25.1	0	22.5	0	21.5	0	17.1	0	12.1	0	9.2
3	4	42.1	—	—	—	—			—	—	—	—	—	—
4	5	44.6	0	31.5	0	27.8	0	26.7	0	22.7	0	17.0	0	14.3
5	6	47.8		—	—	—	—	—	—	—	—	—	—	—
6	8	43.7	0	34.3	0	29.8	0	29.6	0	25.2	0	19.6	0	17.3
7	9	47.2			—	—		—					—	—
8		—	0	36.9	0	32.0	0	32.5	0	28.0	0	21.9	0	19.4
11			1	38.4	1	34.7	1	34.6	0	30.6	0	24.9	0	22.1
14	—		2	40.1	2	36.2	1	36.9	0	32.6	0	26.7	0	23.2
16			4	41.3	2	37.8	1	39.0	0	34.2	0	28.0	0	23.9
18		—	4	43.3	3	36.9	1	40.4	1	33.7	0	29.3	0	24.8
20		—	5	43.5	3	37.2	4	39.0	1	34.5	0	30.3	0	26.1
22			5	45.0	4	38.[illegible]	4	41.2	1	35.7	0	31.7	0	26.7
24		—	6	46.8	4	39.5	6	40.0	1	36.1	0	32.1	0	26.8
26	—	—	6	48.3	4	40.5	6	41.3	1	36.9	0	33.3	0	27.2
28	—	—	9	39.8	5	40.0	8	41.9	2	37.2	0	34.5	0	28.5
30		—	10	40.6	5	41.8	8	43.5	3	36.8	0	34.9	0	29.3
32		—	—		6	[illegible]	9	41.2	4	3[illegible].2	1	36.0	0	30.7
34	—		—	—	7	41.3	9	44.3	4	37.2	1	36.0	0	30.7
36				—	8	40.[illegible]	9	48.7	4	38.6	1	37.6	—	
38		—		—	8	42.0	9	48.7	4	39.1	1	38.4	0	3[illegible].0
40				—	8	4[illegible].8	10	49.7	5	38.1	1	39.6	—	
42	—	—			8	45.5	—		5	39.4	1	40.2	0	33.5
44	—	—	—		10	45.[illegible]	—	—	5	40.3	1	41.0		—
46					—				5	41.7	2	42.2	—	
48	—	—					—		5	42.3	5	43.2	0	35.7
50									5	43.2	5	44.0	—	
53	—			—					8	42.0	7	43.3	—	
56	—	—	—				—	—	8	43.2	10	43.3	2	31.1
58	—	—	—				—	—	10	43.2		—		—
64			—	—				—		—	—	—	5	35.7

TABLE 2 SUMMARIZED ANALYSIS OF DATA LARVAE EXPOSED TO 35° C AND RELATIVE HUMIDITIES OF 0 TO 60%

(Initial moisture content 54% dry matter content 46%, estimated)

	Relative humidity						
	0%	10%	20%	30%	40%	50%	60%
Average longevity (days)	4.2	20.7	27.6	24.1	41.6	49.0	71.5
At death percentage							
Weight loss	48.0	46.2	46.5	45.9	46.6	45.5	45.0
Dry matter (basis initial weight)	36.6	33.8	34.2	32.7	31.3	33.1	33.1
Moisture (basis—initial weight)	15.4	20.0	19.3	21.4	22.1	21.4	21.9
Dry matter (basis —death weight)	70.4	62.9	63.8	60.5	58.7	60.8	60.2
Moisture (basis—death weight)	29.6	37.1	36.2	39.5	41.3	39.2	39.8

TABLE 3.—COMPARISON OF REACTIONS OF LARVAE TO 40° C. AND RELATIVE HUMIDITIES OF 20 TO 80%

Relative humidity	Average longevity	Weight loss
%	days	%
20	1.1	48
40	1.4	49
50	1.4	47
60	2.5	49
70	2.6	42
80	4.6	40

TABLE 4.—SUMMARIZED ANALYSIS OF DESICCATION OF 60 NAKED SAWFLY LARVAE AT 35° C. AND RELATIVE HUMIDITIES OF 10 TO 60%

	Total	Water	Dry matter
Initial weight	927 mg.	500 mg. (54.0%)	427 mg. (46 0%)
Death weight	501 mg.	195 mg. (38.5%)	306 mg. (61 5%)
Percentage loss	46.0%	61.0%	35 3%

matter content, although the total weight will have been reduced. Two similar specimens may undergo vastly different moisture treatments, and end up with similar proportions of moisture and dry matter. Many other possibilities exist, even in the relatively simple cases of non-feeding stages. It is therefore desirable to know as much of the previous moisture history of the material as possible, not only at the beginning of the experiment but often before it as well. If such information is not available, or if it shows that there is considerable variation in the material, then it should be realized that any variation present will be reflected in the results. The experiments reported here will serve as an example. The experimental material was judged to be fairly uniform in most respects, but there were large differences in size as well as some differences in amount and proportion of moisture and dry matter. As it was not feasible to substantially reduce this variation by rigid selection of material, some accuracy was sacrificed. The variations in the data obtained are considered to be too great for precise mathematical analysis of those data, but sufficiently small as not to affect the general conclusions.

MORTALITY IN STUBS EXPOSED TO 40° C. AND 0% R. H.

In order to test the resistance to desiccation of *Cephus cinctus* throughout the entire period that it spends in the stub, collections of stubs were made periodically and exposed to a set of standard drying conditions. In order to reduce the time factor to a workable level, all stubs were exposed to 40° C. and 0% R. H. within a few hours of being brought in from the field. It should be remembered that all stages were non-feeding. The unit sample was 25 stubs, with a few extras being included to allow for mortality

from causes other than desiccation, such as disease and parasitism. The stubs were split open at the end of the exposure period and the mortality of larvae, pupae or adults noted. Collections were made from April 30, 1943, to June 15, 1944, thus including 2 seasons of spring development and 1 of the period spent in diapause from harvest-time to freeze-up. All collections were made from the same field or its adjoining counterpart in a two-year wheat-summerfallow rotation. Table 5 compares the mortality of developing larvae, pupae and adults in the springs of 1943 and 1944, while Table 6 lists the mortality of diapause larvae in the fall of 1943.

Spring-collected larvae varied considerably in their resistance to desiccation in the 2 years. It was impossible in many cases to distinguish between prepupal and non-prepupal larvae after death, and of course it was impossible to know what proportion of each had been present in the sample before drying. Nevertheless, the differentiation was made in sufficient cases that it soon became apparent that prepupal larvae were the more susceptible of the two. This is supported by the 1944 data in Table 5 and to some extent by the 1943 data, which, however, contain too few samples for adequate analysis. A further decrease in resistance to desiccation very definitely takes place during the pupal stage. In fact, it appears to be a fairly uniform, progressive decrease, beginning with the preplpa and proceeding to the adult. Table 5 contains only one column of values for adult mortality, and these are for adults which had not yet left the stubs. Free-flying adults were all killed in 2 or 3 hours at 40° C. and 0% R. H. Not only did adults die more quickly than pupae, but they afterwards dried to a state of brittleness in a shorter time than pupae, while pupae became brittle more rapidly after death than did larvae. In fact, there seems to be the same order of resistance or susceptibility to drying after death as before.

Table 6, dealing with fall-collected larvae, shows that there was a progressive increase in resistance to desiccation during August, followed by an approximately equal decrease during September. No explanation is offered for this fluctuation, or for the even greater change that took place between October 7, 1943, and April 24, 1944 (cf. Table 5). There was no uniformity of results among larvae collected at different times of the year, or in similar seasons of 2 different years. The only safe comparison seems to be with later stages, which were progressively less resistant.

The object of this latter group of tests was to discover at what stage and season the species was most susceptible to desiccation, so that such information could be taken into consideration in making control recommendations. The experimental results clearly indicate that susceptibility increased progressively during the spring as development proceeded from the prepupa to the adult. While the results obtained with larvae exhibit considerable variation, they show a rather high degree of resistance to desiccation at temperatures up to 40° C. Higher temperatures would of course reduce the time necessary to produce lethal desiccation and in addition could become a lethal factor independently of moisture. Nevertheless, the larval stage is the most resistant stage present during a period of about 10 months, from mid-August to mid-June.

TABLE 5.—PERCENTAGE MORTALITY OF SPRING-COLLECTED LARVAE, PUPAE AND ADULTS EXPOSED TO 40° C. AND 0% R. H., 1943 AND 1944

Exposure (days)	Percentage mortality																					
	1943												1944									
	Larvae			Pupae									Larvae					Pupae			Adults
	April	May		May		June							April	May				May	June		June
	30	14	18	27	29	2	4	9	11	16	18	22	24	2	6	12	17	31	7	15	15
1	—	—	20	—	—	—	2	2	34	46	80	73	0	0	0	0	0	0	0	20	0
2	4	—	56	9	10	20	15	77	100	98	100	100	0	0	0	4	0	20	20	80	55
3	52	48	78	47	91	25	—	93	100	100	100	100	0	0	0	0	0	65	75	100	100
4	44	—	—	—	94	—	100	100	—	—	—	—	0	5	0	0	25	—	90	100	100
5	56	92	—	—	100	100	—	—	—	—	—	—	0	0	4	4	10	95	100	100	100
6	80	—	—	—	—	100	—	—	—	—	—	—	4	5	0	0	65	100	100	—	—
7	—	96	—	—	—	—	—	—	—	—	—	—	4	0	0	0	40	100	100	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	32	0	36	0	70	100	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—	—	16	0	20	8	75	100	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—	44	—	72	0	95	—	—	—	—
11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	76	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100	—	—	—	—	—	—

TABLE 6.—PERCENTAGE MORTALITY OF FALL-COLLECTED DIAPAUSE LARVAE EXPOSED TO 40° C. AND 0% R. H.

Exposure (days)	Percentage mortality						
	August			September			October
	10	17	28	4	10	28	7
1	4	4	0	0	0	—	—
2	12	0	0	0	0	16	8
3	48	44	4	8	4	48	24
4	46	78	8	12	32	82	60
5	88	96	12	32	60	86	90
6	97	96	28	52	76	98	100
7	—	88	76	80	96	—	100
8	—	—	52	96	100	—	100
9	—	—	96	100	100	—	100

SUMMARY

At 30° C., and relative humidities of 0 to 50%, naked *Cephus cinctus* larvae lost weight very rapidly at first, then more slowly, losing more than 40% of their original weight before drying from desiccation.

Longevity decreased and rate of weight loss increased as the relative humidity was reduced from 50 to 0%.

At 35° C. (0 to 60% R. H.) and at 40° C. (0 to 80% R. H.) the results were the same as at 30°, except that the time factor was reduced as the temperature was raised. At all temperature and moisture conditions investigated, larvae died only after losing more than 40% of their original weight.

Temperatures up to 40° C. did not in themselves have any lethal effect.

The lack of covering of the larvae, which were removed from the protection of their stubs and cocoons, had no lethal effect in itself.

Death occurred only as a result of desiccation.

During desiccation the amounts of both moisture and dry matter are reduced; but whereas the percentage of moisture decreases, the percentage of dry matter increases.

Freshly collected material exposed in the stubs to a set of standard drying conditions showed considerable seasonal differences in resistance during the 10-month period that the species spends in the stub. Larvae were most resistant to desiccation, although they exhibited considerable variation. Prepupae were less resistant than non-prepupal larvae, and as development proceeded from prepupa to adult the resistance steadily decreased.

Dead specimens showed the same general trend as living specimens in regard to relative susceptibility or resistance to desiccation.

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MOISTURE RELATIONSHIPS OF THE WHEAT STEM SAWFLY (*CEPHUS CINCTUS* NORT.)

II. SOME EFFECTS OF CONTACT MOISTURE[1]

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A previous paper (Salt 1) has dealt with some of the effects of desiccation at high temperatures on larvae, pupae and adults of the wheat stem sawfly. It was shown that while larvae in good condition had a moisture content of roughly 52 to 58%, they lost more than 40% of their original weight before dying from desiccation, at which time their moisture content was less than 40% of their body weight. One of the control measures used against this pest is a shallow tillage operation, designed to remove the "stubs" from the soil and leave them lying on the surface of the ground, exposed to desiccation, high temperature, predators and possibly other unfavourable factors. Desiccation, in combination with high temperature, appears to be the most important of these factors. The drying of larvae in exposed stubs in the field is an intermittent process in most cases, as periods of hot, dry weather are interspersed with cooler, moister weather which may be accompanied by occasional rain. It is with the effects of moistening or wetting the stubs and larvae that this paper is concerned.

In order to find out whether larvae actually gained in weight when placed in contact with moisture, they were removed from the stubs and placed individually between layers of damp cellucotton. Larvae were weighed periodically to the closest tenth-milligram. In this way, the variation in weight of an individual could be followed, but its moisture content remained unknown until the end of the experiment. In other experiments, stubs were exposed to contact moisture over a period of days, the moisture content of samples being taken at specified intervals. A check sample, not exposed to contact moisture, was also taken. The moisture content was arbitrarily determined by oven-drying at 95° to 100° C. for 24 hours, by which time the weight had become constant. A variation of the second group of experiments consisted in comparing the daily mortality in soaked and unsoaked stubs when exposed to 40° C. and 0% R. H. This experiment is summarized in Table 1. The stubs received identical treatment except that the "wet" stubs were submerged in tap water for 1 minute, drained and kept in a closed glass jar for 4 days.

After 4 days' contact with moisture the "wet" larvae increased in moisture content from 51.3 to 55.3%, a significant change. While this fact is of considerable importance in the problem under consideration, Table 1 contains other interesting data. Mortality was delayed by the moisture treatment, yet the last column shows that the 4% increase in moisture content which was gained in 4 days as a result of this treatment, was lost by the end of 1 day at 40° C. and 0% R. H. If the change in moisture content is all that is involved, then the mortality of the wet series

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TABLE 1.—COMPARISON OF DAILY MORTALITY, AND PERCENTAGE MOISTURE CONTENT OF SURVIVORS, OF LARVAE IN "WET" AND "DRY" STUBS EXPOSED TO 40° C. AND 0% R. H.

No. days exposure	"Dry" series		"Wet" series	
	Mortality	Moisture content of survivors	Mortality	Moisture content of survivors
	%	%	%	%
0	0	51.3	0	55.3
1	32	42.8	4	51.7
2	92	—	0	50.7
3	96	—	4	50.7
4	100	—	28	48.7
5	—	—	24	50.2
6	—	—	36	51.2
7	—	—	36	49.5
8	—	—	52	48.3
9	—	—	52	49.7
10	—	—	92	—
11	—	—	92	—

should equal that of the dry series for the previous day. This is not the case, but is an indication that the soaking not only raised the moisture content, a change that was readily reversible, but also caused a more permanent physiological change. No attempt is made here to explain this change, and for the purposes of this paper the main point in Table 1 is the increase in moisture content of larvae from 51.3% to 55.3% when exposed to a moderate amount of contact moisture for 4 days.

Further proof that larvae increase their moisture content when the stubs are in contact with moisture was obtained incidentally from other experiments. In one, 650 stubs with an initial moisture content of 51.6% (on the basis of a sample) were submerged in tap water for 1 minute, drained, and kept in a closed glass jar for 9 days. At the end of this time, a sample of 25 larvae had a moisture content of 58.4%. In another instance, 200 stubs were removed from storage in a root cellar in November 1944 and placed in a desiccator at 25° C. and 0% R. H. The initial moisture content of a sample of 10 larvae was 56.3%, a figure which was gradually reduced by desiccation until on January 3, 1945, the moisture content of a sample was 50.5%. On this date, the stubs were placed upright in a tin, covered with sifted loam of 14.0% moisture content, and the lid sealed with adhesive tape. Samples were removed periodically and the moisture content of 10 larvae was determined. Toward the end of the experiment pupae began to appear in the stubs. These were discarded, so that the figures listed in Table 2 represent the moisture content of 10 larvae. The soil in which the stubs were placed was sifted through a 20-gauge wire screen, so it was far from wet. Yet it was sufficiently damp to supply contact moisture to the stubs and the larvae within them. The moisture content of the larvae increased definitely, though somewhat irregularly. Nevertheless it amounted to 7 or 8% and supports the conclusion that the moisture content of larvae can increase under such conditions.

TABLE 2.—PERCENTAGE MOISTURE CONTENT OF LARVAE EXPOSED (IN STUBS) IN SOIL OF 14.0% MOISTURE CONTENT, AT 25° C.

No. days exposure	No. prepupae in sample of 10 larvae	Moisture content	No. days exposure	No. prepupae in sample of 10 larvae	Moisture content
		%			%
0	0	50.5	17	2	57.6
2	1	53.3	20	1	58.1
5	1	52.8	25	0	56.8
8	0	56.1	30	1	59.3
10	1	55.0	35	0	58.9
12	1	55.7			

The percentage moisture content of an insect, however, is the ratio of moisture to total weight, the latter being the sum of moisture plus dry matter. The percentage of moisture can therefore increase in any of 3 ways, (1) an increase in actual amount of moisture, (2) a decrease in actual amount of dry matter, and (3) a proportionate increase in moisture. In the above experiments there probably was some loss in dry matter, especially at the longer exposures. It would hardly be sufficient, however, to account for the relatively large increases in percentage moisture content. Further experiments showed that moisture is actually taken up by the insect, so that the increase in percentage moisture content values can be interpreted as an actual increase in the amount of moisture.

The first experiment using larvae removed from the stubs was an extreme case. Seven diapause larvae which had been severely desiccated in another experiment were weighed and placed between layers of damp cellucotton at 22° C. Although the exact moisture content of these seven specimens was of course unobtainable, yet on the basis of other specimens in the desiccation experiment it is certain that they had a moisture content of less than 45%. The treatment of each larva before the experiment and its reaction to the contact moisture are given in Table 3.

TABLE 3.—CHANGE IN WEIGHT OF PARTIALLY DESICCATED DIAPAUSE LARVAE WHEN PLACED IN WET CELLUCOTTON AT 22° C.

No. days 40° C., 0% R.H.	Initial		Weight at				Condition at 22 d.
	Condition	Weight	1 d.	4 d.	14 d.	22 d.	
		mg.	mg.	mg.	mg.	mg.	
5	Feeble	8.0	8.0	8.0	8.8	8.8	Active
5	Feeble	4.3	4.5	4.5	6.0	(moulded)	Dead
6	Feeble	6.6	6.8	6.7	7.6	7.6	Active
4	Very feeble	6.8	7.0	7.1	8.5	10.0	Active
4	Very feeble	3.2	3.2	3.1	4.[illegible]	4.7	Very feeble
5	Sluggish	9.6	9.8	9.6	10.5	10.6	Active
5	Sluggish	6.0	6.0	5.9	6.8	6.9	Active
Percentage increase in weight			1.6	0.0	17.2	20.9	—

ll of the larvae had gained weight by the end of the experiment and em returned to an apparently healthy state. The increase in weight started several days after the beginning of the experiment but the weighings were too infrequent to show any detail. A more careful experiment was therefore started, using 20 diapause larvae. These were kept separately between layers of damp cellucotton, which was replaced weekly. No trouble was experienced from mould. The larvae were selected for size, forming a group of 10 large larvae (average weight 9.9 mg., range 8.0 to 14.1 mg.) and 10 small larvae (average weight 3.5 mg., range 2.7 to 4.1 mg.). The large larvae were actually much closer to an average weight (8 to 10 mg.) than the small ones.

The use of 2 size groups was a result of numerous casual observations which had indicated that their reactions to many factors were distinctly different. The size of *C. cinctus* larvae is presumably dependent on physiological factors (chiefly nutrition, in turn dependent on that of the host plants) as well as genetic factors. On size depend the ratios, for example, of surface area and tracheal area to body weight, both of which are probably important in any consideration of moisture intake or loss. The rate of post-diapause development bears in this species a direct relationship to size.

A sample of 11 larvae from the same stock as the experimentals had a moisture content of 42.7%. Like those in Table 3 these larvae were severely desiccated and were in diapause.

Figures 1A and 1B show the increase in weight of the larvae during the experiment. Three larvae in each series were removed on the 15th day for a moisture content determination. Each of these was of average behaviour from the standpoint of weight increase; their moisture contents will be discussed later. One larva in each series died before the 15th day—a large one on the 40th day after a phenomenal weight increase, and a small one on the 24th day after virtually no increase. All of the remaining 6 large larvae, and 3 out of 6 small larvae, were alive and apparently healthy when the experiment ended on the 79th day. It should be noted that the 3 small larvae which survived had more moderate weight increases than those which died. It would have been interesting to follow all of these larvae up to the time of their death, but their moisture content was desired and on the 79th day they were weighed and placed in the electric oven.

In the first 9 days some larvae lost a small amount of weight, although this is not shown in the figures. The small larvae required a few days to register an increase, while a few large ones began to gain immediately. Except in one case (the fatal one) and to some extent one other, the large larvae were fairly uniform in their reaction to contact moisture. The small larvae were more irregular both as individuals and as a group. Temporary losses or failure to gain were more common with them. It would be difficult to choose an average or normal curve for small larvae, while this would be relatively simple for large larvae.

The 4 whose weight increases were notably greater than those of the others, all died before the end of the experiment. Whether they died as a result of their remarkable absorption of moisture or whether the absorption

followed some physiological disturbance is not known. At any rate, the individuals having the flatter weight-increase curves were more healthy and may be considered more normal than the others, since the duration of treatment is admittedly extreme.

It is apparent then that sawfly larvae can absorb contact moisture, the word "absorb" being used in a broad sense. While the possibility of the larvae drinking moisture, or eating cellucotton, was not entirely ruled out

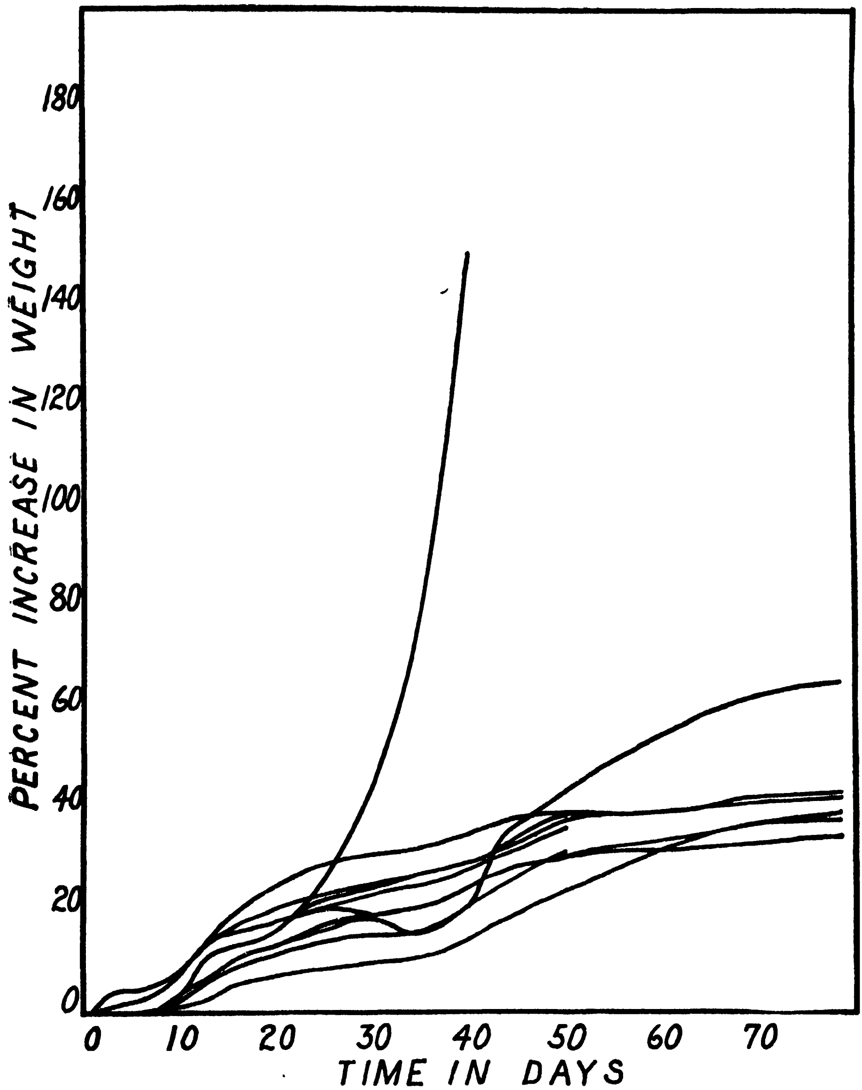

FIGURE 1A. Increase in weight of 10 large, naked, diapause *Cephus cinctus* larvae exposed to contact moisture at 22° C.

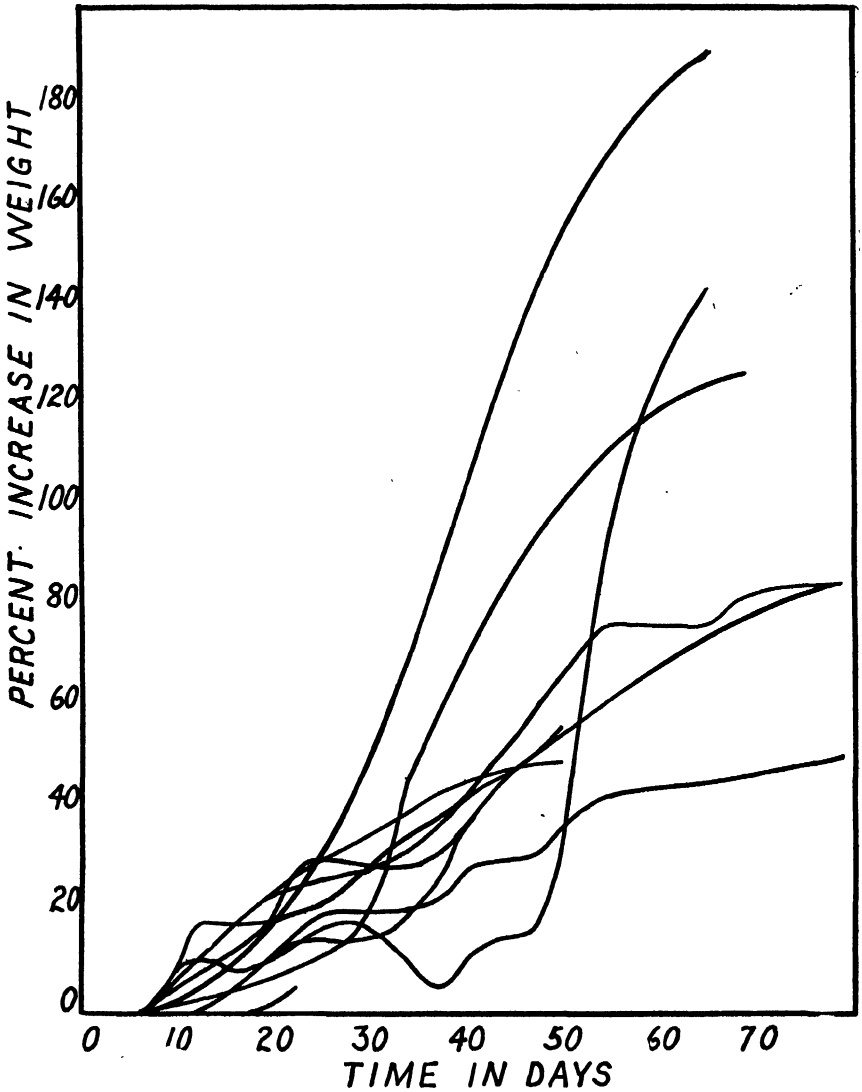

FIGURE 1B. Increase in weight of 10 small, naked, diapause *Cephus cinctus* larvae exposed to contact moisture at 22° C.

in this experiment, it seems very unlikely that this occurred. The larvae at this stage are in a normally overwintering, diapause condition and have completed feeding some time before forming their cocoons. The ingestion of solids would be detrimental to them at this time, although watery liquids might not be harmful.

Temporary loss of weight occurred in some specimens. This is considered to indicate that the utilization of solids during metabolism was greater than the absorption of moisture. Minor losses of weight may have

been due to the experimental error in weighing, which amounted to ± 0.1 mg., or about 1% in large larvae and 3% in small larvae. One small larva, however, lost weight far in excess of the experimental error, and then recovered, to gain 144% before its death on the 75th day.

As previously mentioned, 3 larvae in each series were oven-dried on the 15th day of exposure. The oven-dry weight was taken to be the weight of dry matter, and the loss in weight during drying was considered to be moisture. In addition, the dry matter and moisture content at the start of the experiment was calculated on the basis of the figures for the controls, namely, 57.3% dry matter and 42.7% moisture. Table 4 lists the recorded and calculated weights, while Table 5 contains an analysis of them.

TABLE 4.—WEIGHTS OF SAMPLE LARGE AND SMALL LARVAE AFTER 0 AND 50 DAYS' EXPOSURE TO CONTACT MOISTURE AT 22° C.

No.	Initial weight			Weight at 50 days		
	Total	Calculated dry matter	Calculated moisture	Total	Dry matter	Moisture
	mg.	mg.	mg.	mg.	mg.	mg.
L4	8.0	4.6	3.4	11.0	4.0	7.0
L5	9.3	5.3	4.0	12.3	4.1	8.2
L8	9.7	5.6	4.1	13.5	4.9	8.6
S3	3.5	2.0	1.5	5.5	1.4	4.1
S4	3.5	2.0	1.5	5.2	1.5	3.7
S9	3.7	2.1	1.6	5.8	1.6	4.2
Total large	27.0	15.5	11.5	36.8	13.0	23.8
Total small	10.7	6.1	4.6	16.5	4.5	12.0

TABLE 5.—COMPARISON OF REACTIONS OF SAMPLE LARGE AND SMALL LARVAE TO 50 DAYS' EXPOSURE TO CONTACT MOISTURE AT 22° C.

Size	%		% Change			Ratios of % change		
	Dry matter	Moisture	Total weight	Dry matter	Moisture	Moisture / Total	Dry matter / Total	Moisture / Dry matter
Large	35	65	+36	−16	+107	2.97	0.44	6.7
Small	27	73	+54	−26	+161	2.98	0.48	6.2

Percentage figures in Table 5 are given to the nearest integer because of the experimental error in weighing.

In each series the moisture increase was considerably greater than the dry matter decrease, thereby producing a substantial net gain in weight. Comparing the 2 series it is seen that the small larvae gained roughly 50% more moisture and lost about 60% more dry matter than the large larvae (on the basis of body weight in each case). The relative changes, however, were similar in each size group, as shown in the last 3 columns of Table 5. This indicates that any difference in the 2 sets of figures for percentage of weight change is one of extent rather than of composition.

Even though these sample larvae were selected for average weight increase during the first 50 days of the experiment, the small larvae appear to be more extreme in their reactions to contact moisture than the larger ones. This is apparent also in Figures 1A and 1B. Taking into consideration not only these and other experimental studies on sawfly larvae but also field observations, it should perhaps be re-stated here that the large larvae in the above experiment are somewhat more representative of a normal population than the smaller ones The size and apparent state of health of larvae varies considerably in nature, depending chiefly on the condition of the host plants during larval development, which in turn is dependent on a complexity of factors

After removing 3 samples at 50 days, each group contained 6 larvae. All of the 6 large larvae lived until the end of the experiment at 79 days Three small larvae died between 65 and 79 days, and each of these was an extreme case In Table 6 the data for these 3 are treated separately from the 3 larvae which reacted more normally.

TABLE 6—COMPARISON OF REACTIONS OF LARGE AND SMALL LARVAE TO CONTACT MOISTURE AT 22° C FOR 65 TO 79 DAYS

Size	No days exposure	%			% Change		Ratios of % change		
		Dry matter	Moisture	Total weight	Dry matter	Moisture	Moisture / Total	Dry matter / Total	Moisture / Dry matter
Large	79	28	72	+ 44	−31	+144	3 27	0 70	4 6
Small (average)	79	20	80	+ 74	−39	+221	2 86	0 53	5 7
Small (extreme)	65 to 79	15	85	+155	−31	+400	2 58	0 20	12 9

In the period after 50 days' exposure, larvae continued to gain moisture and lose dry matter but the proportions were not similar in the 2 groups as they had been at 50 days The 3 small larvae which died at 65 to 79 days gained a much greater proportion of moisture. Both large and small larvae which survived the full period of the experiment used up more dry matter per unit increase in either total weight or moisture than at 50 days.

DISCUSSION

The ability to absorb moisture is of great importance to sawfly larvae in their natural environment, for it has already been shown that they lose moisture with comparative ease (Salt 1). As one control measure is aimed at exposing the larvae to lethal desiccation during hot, dry weather, the ability of the larvae to absorb moisture if the stubs become dampened by rains counteracts the desiccation if it has not already proved fatal. The experimental work so far has included only desiccation at temperatures up to 40° C. and the absorption of moisture chiefly at 22° C. Further study at temperatures closer to the upper lethal limit would undoubtedly prove of practical importance and theoretical interest, for in the desiccation

studies previously reported temperature was considered of practical importance only insofar as it affected desiccation. The two factors are of course inseparably linked, along with a third factor, time.

SUMMARY

Diapause larvae of *Cephus cinctus* Nort. readily absorbed contact moisture, often in large amounts, at room temperature. Some dry matter was lost as a result of physical activity and general metabolism.

While absorbing contact moisture and losing small amounts of dry matter the wet weight increased, the percentage moisture content increased and the percentage of dry matter decreased With three factors changing, the picture is best expressed by the values for percentage change of total weight, moisture and dry matter.

Small larvae were erratic and in many cases extreme in their absorption of contact moisture. Large and average-sized larvae reacted more moderately. As most of the larvae used in these experiments were rather severely desiccated to begin with, the changes listed may be considered maxima.

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RESPONSE OF BURLEY TOBACCO VARIETIES TO IONIC FORMS OF NITROGEN[1]

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Knowledge of hereditary variation in plant nutrition is at present very limited. Hoffer (6) found that 13 inbred lines of corn and 2 hybrids gave differential growth on clay and loam soils. Five barley varieties differed significantly in their response to 3 levels of N, P, and K in all combinations, according to Gregory and Crowther (2). Smith (14) reports finding a differential response between inbred lines of corn on low phosphorus levels and, to a lesser degree, on low nitrogen. The findings of Lyness (10) with inbred strains and hybrids of corn on different levels of phosphorus and nitrogen were in close agreement with those of Smith. Stringfield and Salter (15) and Lamb and Salter (8) (9) conducted a corn-oats-wheat rotation on 4 levels of fertility in which corn varieties and hybrids showed a significant 'variety × level of fertility' interaction 2 years out of 5. Wheat gave significant interaction with fertility levels for 5 years but oats did not. Harvey (4) reports a differential response by corn strains and hybrids to ammonium and nitrate nitrogen and a differential response by tomato strains of 2 species to low levels of N, P, and K as compared to full nutrient solutions.

This paper deals with the response of two burley varieties of tobacco, namely, Harrow Velvet and Kelley, to nitrate and ammonium nitrogen.

MATERIALS AND PROCEDURE

The seeds of the 2 tobacco varieties were set out on July 15, 1941, on moist filter paper to germinate and, on July 25, the seedlings were planted in Nepean sandstone in 3 in. pots. All plants were supplied with a uniform nutrient solution containing no ammonium nitrogen. This solution was made from $Ca(NO_3)_2$, KH_2PO_4, and $MgSO_4$ in the ratio 8 : 2 : 5, with minor elements added. On September 22, 1941, the plants were potted in 3-gallon pots containing 45 pounds Nepean sandstone, 1 plant per pot. Water only was supplied the plants until September 29, when it was replaced by nutrient solutions which were supplied by the constant flow drip method. Four nutrient solutions were used. These ranged from 100% NO_3^-, decreasing NO_3^- nitrogen and increasing NH_4^+ nitrogen in increments of $\frac{1}{3}$ of the total nitrogen to 100% NH_3^+ nitrogen. The concentrations of N, Ca, and K were constant in all treatments. S was supplied at a concentration of 45, 93, 140, and 189 p.p.m. and P at a concentration of 196, 228, 265, and 253 p.p.m. in treatments 1, 2, 3, and 4, respectively. The minor elements B, Mn, and Zn were supplied at the rate of 0.5 p.p.m. and Fe at the rate of 3.0 p.p.m. in all treatments.

The plants were harvested 3 months after planting in 3-gallon pots. Fresh weights were taken of 4 fractions of the tissue: the tops, consisting of the portion of the plants usually removed by "topping"; the top leaves;

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the bottom leaves; and the stalks. These fractions were diced, thoroughly mixed, and aliquots weighed out for the dry-weight determinations and for chemical analyses of all except the first-named fraction.

RESULTS

The growth data are contained in Table 1. The % dry weight per plant is a calculated value since the actual % dry weight determinations were based on the 4 stated fractions of the tissue. Additionally, the average fresh weights are presented graphically in Figure 1.

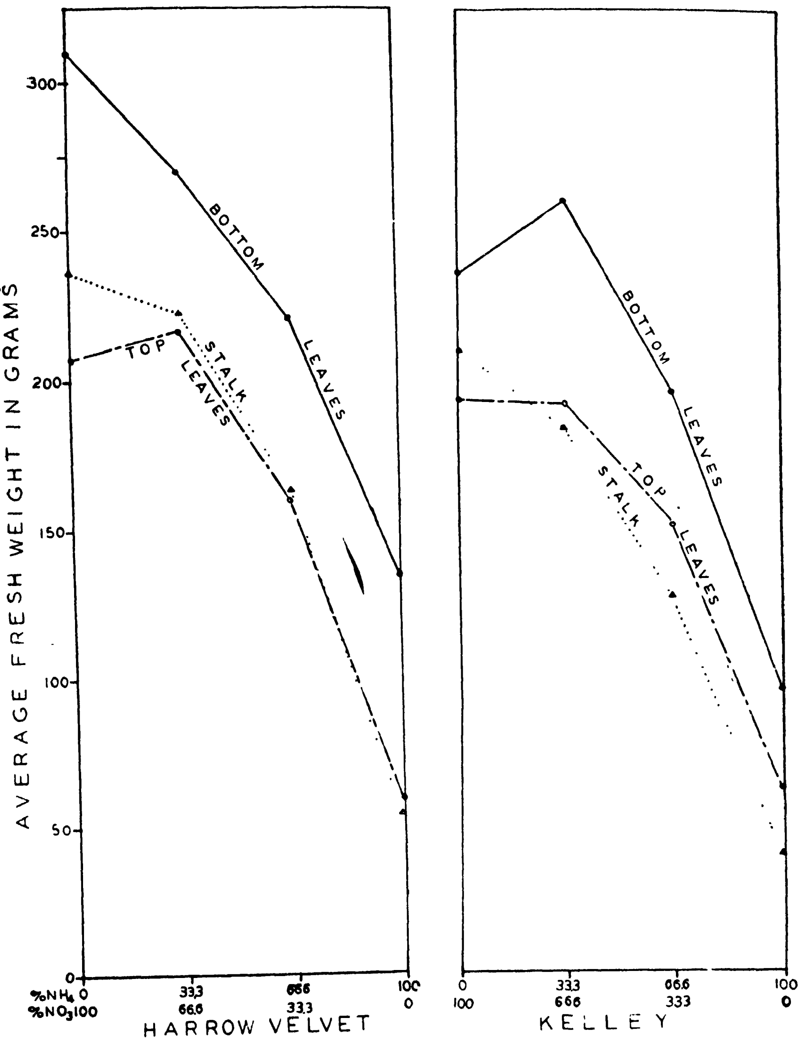

FIGURE 1. Growth response of tobacco varieties to ionic forms of nitrogen.

A summary of the analysis of variance based on total fresh weight data is presented in Table 2. The mean square for varieties is above the 1% level, as measured by its P value, and the value given in Table 10.2 of Snedecor's "Statistical Methods" 1938. This is true also of the mean square for solutions. Therefore, both varieties and solutions were sources of significant variation. The 'varieties × solutions' mean square lies below the level of significance (below the 5% level). Thus, the differential varietal response to solutions was not significant under the conditions of this test.

The mean fresh weights of both varieties on the 4 nutrient solutions are presented in Table 3. The difference necessary for significance = 51 8 (P = 05) The mean yield on each of solutions 1 and 2 is significantly greater than that on either solution 3 or 4, while no significance can be assigned to the difference between solutions 1 and 2. From this it is apparent that the plants of each variety differed in their response to nitrate versus ammonium nitrogen. A concentration of ⅓-ammonium nitrogen in the nutrient solution did not have a significant effect on yield as compared to all-nitrate nitrogen; but, above this level, a progressive increase in the proportion of ammonium nitrogen resulted in a progressive decrease in yield.

TABLE 1 —YIELD IN GRAMS OF VARIETIES GROWN WITH CONSTANT NITROGEN SUPPLY BUT VARIOUS PROPORTIONS OF NITRATE AND AMMONIUM IONS

Treatment No	Ionic proportions		Variety	Average fresh weight per plant					Ave dry weight per plant
	NO_3^-	NH_4^+		Top	Top leaves	Bottom leaves	Stalk	Total	
1	All	0	Harrow Velvet	15 8	206 9	308 7	235 5	766 9	68 29
			Kelley	82 6	193 4	236 0	210 2	722 2	61 35
2	⅔	⅓	Harrow Velvet	129 0	217 4	270 2	222 7	839 3	75 52
			Kelley	109 1	191 9	260 7	184 2	745 9	63 28
3	⅓	⅔	Harrow Velvet	80 2	160 0	222 9	163 0	626 1	62 67
			Kelley	91 7	151 9	197 4	127 8	568 8	47 41
4	0	All	Harrow Velvet	11 0	68 0	130 2	52 8	262 0	22 40
			Kelley	42 8	61 4	96 8	39 2	240 2	18 17

TABLE 2 —ANALYSIS OF VARIANCE BASED ON TOTAL FRESH WEIGHT OF PLANTS

Source of variation	Degrees of freedom	Mean square	Calculated F values	Significant F values	
				5%	1%
Varieties	1	44,199 84	11 20**	4 08	7 31
Solutions	3	714,233 12	180 92**	2 84	4 31
Varieties × Solutions	3	5,274 10	1 34	2 84	4 31
Error	40	3,947 83	—	—	—
Total	47				

** Highly significant.

TABLE 3.—MEAN TOTAL FRESH WEIGHT IN GRAMS OF BOTH VARIETIES

Solution No.	Ionic proportions		Mean fresh weight
	NO_3^-	NH_4^+	
1	All	0	744.7*
2	$\frac{2}{3}$	$\frac{1}{3}$	790.3
3	$\frac{1}{3}$	$\frac{2}{3}$	598.1
4	0	All	251.0

* Difference necessary for significance ($P = 0.05$) = 51.8

The plants grown on high ammonium manifested symptoms of magnesium deficiency (sand drown) and a brown discoloration of the roots.

CHEMICAL ANALYTICAL RESULTS

The results of the analyses of the plants for N, P, K, Ca, Mg, and S, reported as percentage of the dry weight of the samples of ground tissue, are the averages of closely-agreeing duplicate analyses. The methods used in the analyses were the official methods of the A.O.A.C. (11) with one exception—total nitrogen was determined by the method of Pucher *et al.* (12).

The data representing the concentration of the 6 elements studied are given in Table 4 and are presented for each of the 6 elements individually in graphic form in Figures 2 to 7.

The effect of the ionic forms of nitrogen in the nutrient solution on the content of nitrogen in the plant tissues is shown in Figure 2. In general, the curves show an acceleration of accumulation of nitrogen in all 3 fractions of the tissue with increase in ammonium nitrogen and decrease in nitrate nitrogen in the nutrient solution. The curves deviate downward only slightly for the top leaves of both varieties and the stalk of Harrow Velvet at the point where the $NO_3^- \cdot NH_4^+$ ratio was 2 : 1 (treatment 2). Both varieties accumulated nitrogen from NO_3 at approximately the same rate, but Kelley accumulated nitrogen in both leaf tissues and in the stalk tissue at a greater rate than did Harrow Velvet at the NH_4^+ end of the solution. This indicates that the 2 varieties differ in their capacity for selective utilization of ionic forms of nitrogen; however, the varietal difference in this regard was not statistically significant.

The accumulation of phosphorus in the top leaves (Figure 3) was associated with increasing NH_4^+ and decreasing NO_3^- in the nutrient supply in treatment 1, 2, and 3 but was depressed slightly at 100% NH_4^+ nitrogen. The accumulation of phosphorus in the bottom leaves was relatively unaffected by variation in the ionic proportions in the substrate, increasing only slightly from treatments 1 to 3, and decreasing at 100% NH_4^+ nitrogen. In the stalk, the content of phosphorus increased markedly from treatments 1 to 2, then slightly to the NH_4^+ end of the solution. The curves for both varieties are very similar.

Figure 4 shows that potassium accumulated in the stalk tissue with decreasing NO_3^- and increasing NH_4^+ in the substrate. However, in both top leaves and bottom leaves of both varieties, the potassium content

TABLE 4.—A SUMMARY OF THE MINERAL ANALYSES OF TOP LEAVES, BOTTOM LEAVES, AND STALK TISSUE EXPRESSED AS % OF DRY WEIGHT

Treatment No.	Ionic proportions		Variety	Top Leaves						Bottom Leaves						Stalk					
	NO_3^-	NH_4^+		N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
1	All	0	Harrow Velvet	5.19	0.59	5.55	3.21	0.39	0.75	4.19	0.54	6.65	3.42	0.62	0.56	2.26	0.34	5.21	1.43	0.11	0.22
			Kelley	5.34	0.54	5.59	3.47	0.38	0.71	4.23	0.54	6.56	3.92	0.66	0.47	2.42	0.32	5.34	1.49	0.14	0.23
2	¾	¼	Harrow Velvet	5.14	1.02	6.23	2.50	0.36	1.26	4.32	0.56	6.91	3.06	0.45	1.30	2.02	0.54	5.13	1.29	0.13	0.27
			Kelley	5.25	0.88	6.03	2.85	0.34	1.08	4.54	0.55	7.15	2.77	0.56	1.31	2.65	0.58	5.27	1.32	0.13	0.31
3	¼	¾	Harrow Velvet	5.36	0.92	6.16	2.12	0.27	1.07	4.58	0.63	5.77	2.33	0.36	1.50	2.17	0.61	4.25	0.87	0.09	0.41
			Kelley	6.03	1.09	5.50	1.93	0.24	1.11	5.75	0.54	5.75	2.41	0.30	1.47	3.06	0.61	4.01	1.01	0.11	0.24
4	0	All	Harrow Velvet	6.17	0.94	5.04	1.82	0.28	0.63	5.10	0.56	5.30	1.61	0.33	1.01	2.64	0.63	4.12	0.87	0.17	0.26
			Kelley	6.61	0.96	5.25	1.59	0.25	0.60	6.32	0.51	5.56	1.83	0.36	1.05	3.14	0.61	3.92	0.95	0.21	0.22

increased from the all-NO_3^- level to a maximum concentration at the $\frac{2}{3}$-NO_3^- level, then decreased markedly with increments of NH_4^+ in the substrate. Also, at high NO_3^- supply, the accumulation of potassium was appreciably greater in the bottom leaves than in the top leaves; but, at high NH_4^+ supply, the potassium content of both top and bottom leaves was approximately equal. Both varieties responded similarly.

From Figure 5, it is evident that variations in the relative proportions of the ionic forms of nitrogen in the substrate had a very pronounced

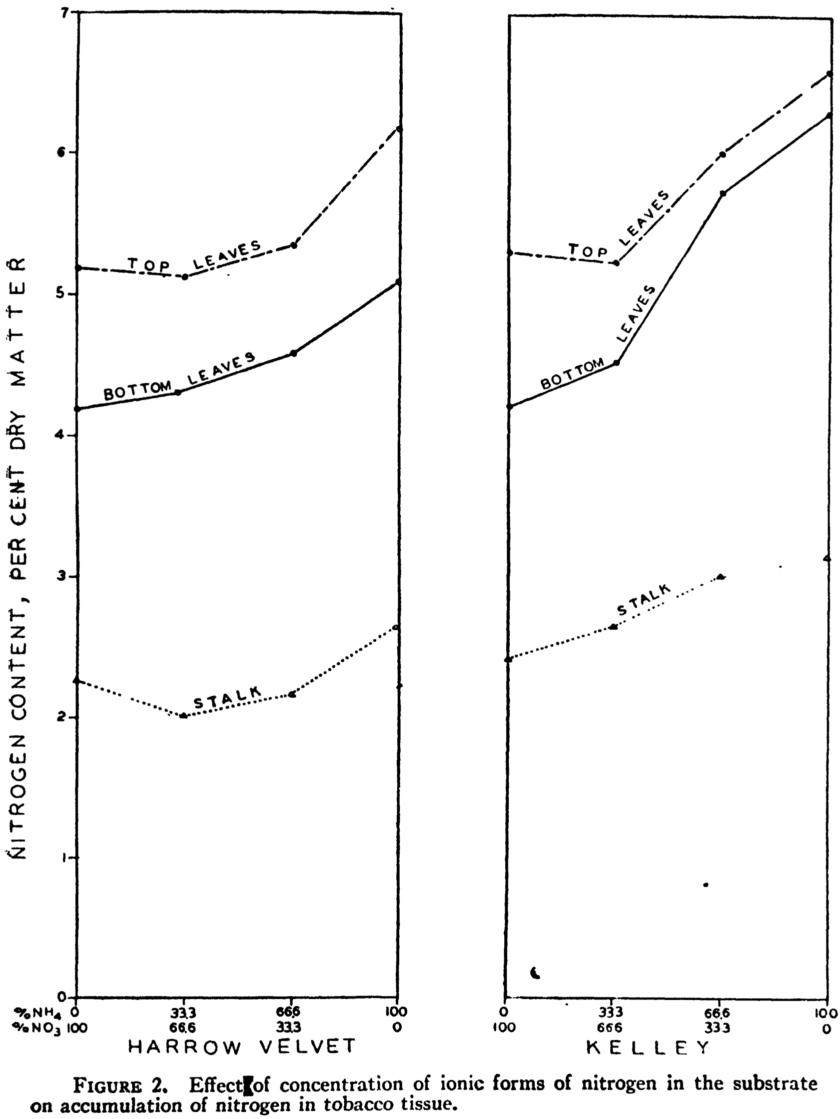

FIGURE 2. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of nitrogen in tobacco tissue.

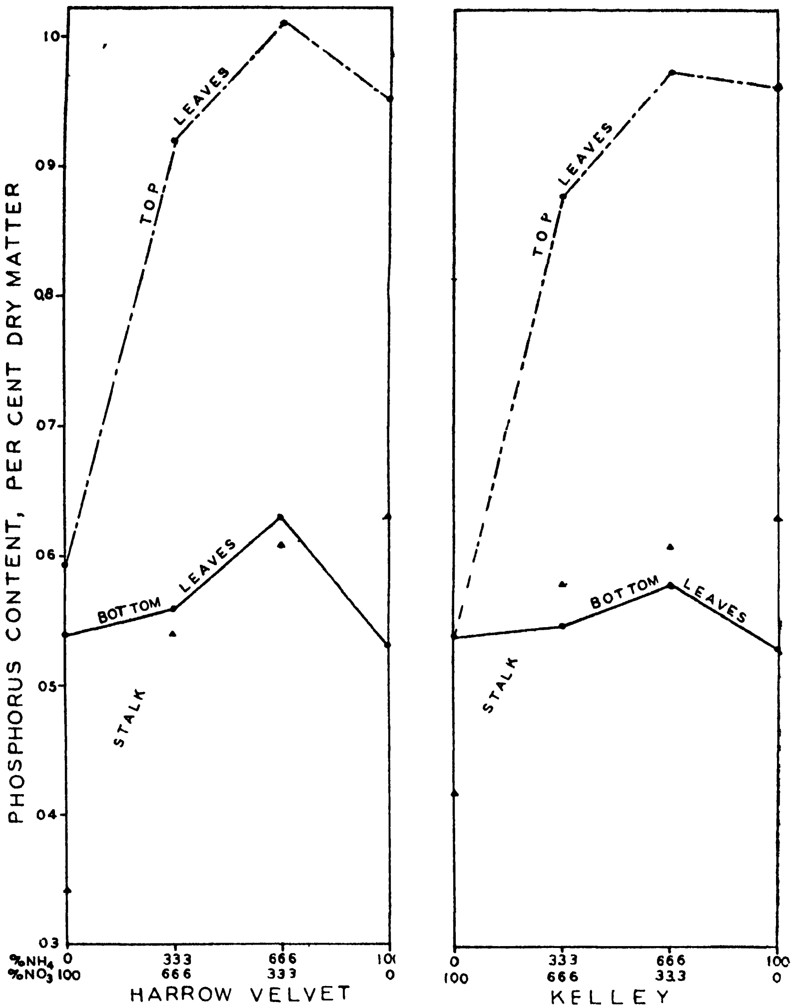

FIGURE 3. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of phosphorus in tobacco tissue

influence on the accumulation of calcium in the tissues. Each successive edcrease in NO_3^- and increase in NH_4^+ in the nutrient supply had a depressing effect on the accumulation of calcium in all 3 fractions of the tissue. The difference between the 2 varieties in this regard was insignificant.

Figure 6 shows a highly depressing effect of the NH_4^- ion on the accumulation of magnesium in the leaf tissue. The magnesium content of both top leaves and bottom leaves decreased markedly with decreasing NO_3^- and increasing NH_4^+ in the substrate over the range 0 to $\frac{2}{3}$ NH_4^+, then increased slightly at the all-NH_4^+ treatment, except in the bottom leaves of Harrow Velvet. In both varieties, the magnesium content was

highest in the bottom leaves, next highest in the top leaves, and lowest in the stalk. The content of magnesium in the stalk was very constant in treatments 1, 2, and 3, but rose appreciably in the all-NH_4^+ treatment. The varietal difference with regard to magnesium accumulation in the tissues was not significant.

A low content of sulphur (Figure 7) in the top leaves was associated both with all-NO_3^- nitrogen and also with all-NH_4^+ nitrogen in the substrate, but the accumulation of sulphur increased markedly in treatments 2 and 3. In the bottom leaves, the accumulation of sulphur was depressed greatly at 100% NO_3^- and reached a maximum concentration at the $\frac{2}{3}$-NH_4^+ nitrogen level. In the stalk tissue, the influence of the ionic forms of nitrogen on

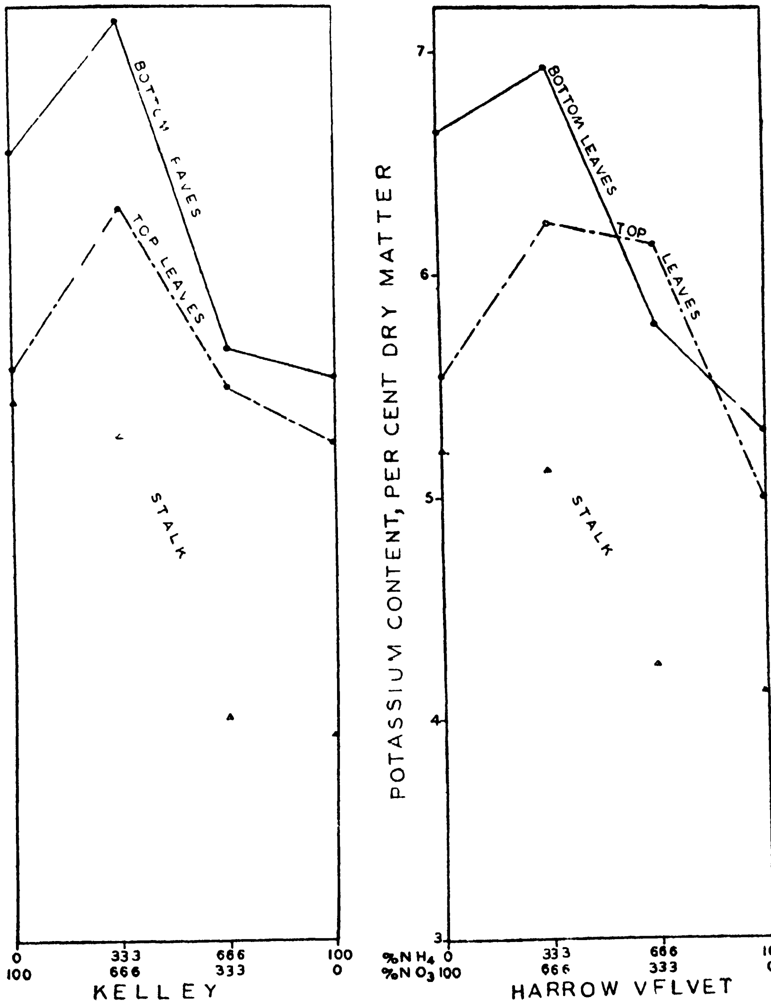

FIGURE 4. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of potassium in tobacco tissue.

the content of sulphur was not pronounced; however, the amount of this element was apparently depressed at both high NO_3^- and high NH_4^+. The 2 varieties did not differ significantly with regard to sulphur accumulation.

DISCUSSION

Inherent physiological differences between plant species are a matter of common knowledge, and such differences have been recognized within a limited number of species. However, no report of physiological studies of varietal differences in tobacco has even come to the attention of the writer.

In the present study in which the fresh weight yield has been the criterion of growth, the differential varietal response of burley tobacco to ionic forms of nitrogen was not statistically significant That is, the

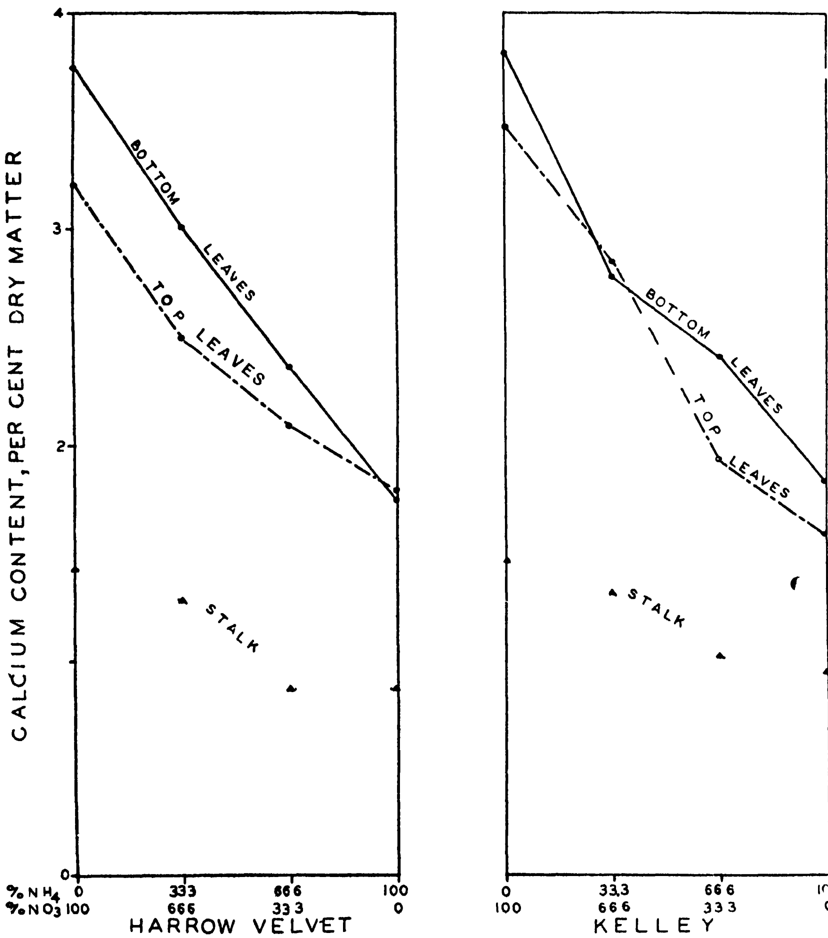

FIGURE 5 Effect of concentration of ionic forms of nitrogen in the substrate on aucumulation of calcium in tobacco tissue.

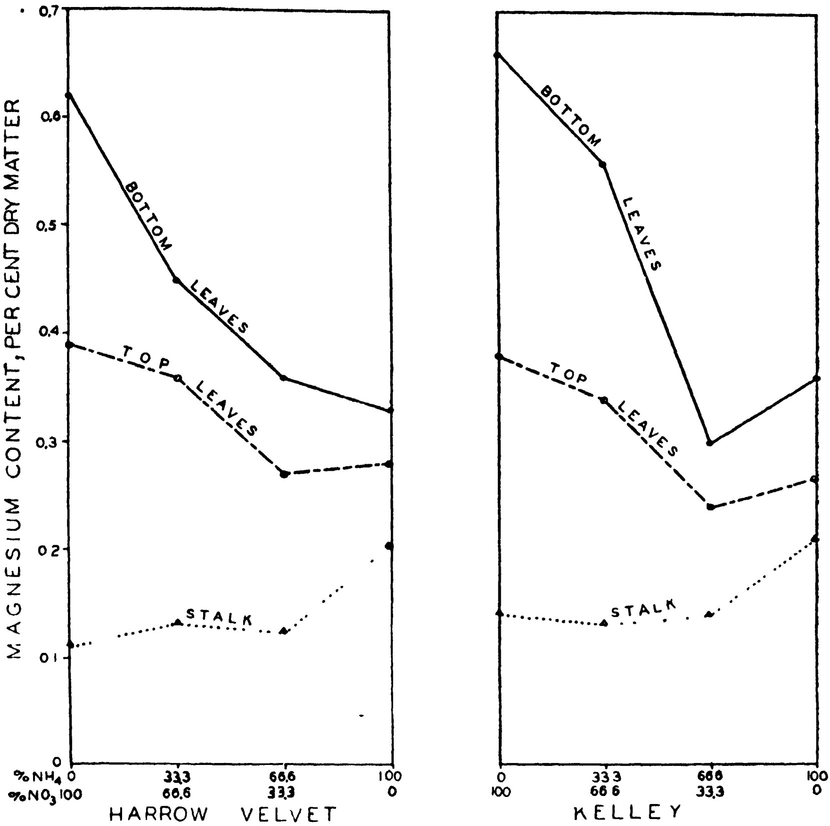

FIGURE 6. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of magnesium in tobacco tissue.

growth of one variety on nitrate nitrogen relative to its growth on ammonium nitrogen did not differ significantly from that of the other variety. However, both varieties made significantly better growth when all, or $\frac{2}{3}$, of the nitrogen supply was in the nitrate form, the yield decreasing with increments of ammonium nitrogen. Thus it is indicated that both varieties are characterized by the ability to utilize nitrate nitrogen more efficiently than ammonium nitrogen as they were supplied in this test. Also, the yield of Harrow Velvet was significantly higher than that of Kelley over the entire range of nutrient solutions.

The chemical analytical data, giving the content of the nutrient elements in the plant material at harvesting time, show a pronounced influence of the concentration of ionic forms of nitrogen, in the nutrient solution, on the accumulation of the nutrient elements in the plant, and an explanation of this influence is sought.

It is generally acknowledged that the rate of absorption of nutrient ions by the roots is a function of the concentration of the ions in the nutrient medium, however, other factors are involved. Ions differ widely in the

rapidity with which they are absorbed and the rate of absorption is related to their mobility. There is evidence that K^+ is absorbed more rapidly than Mg^{++}, and the latter more rapidly than Ca^{++} (13) (3). The anions dealt with in the present study may be arranged in order of decreasing rate of penetration as follows $NO_3^- > H_2PO_4^- > SO_4^=$ (13)

That one ion may affect the absorption of another is well known and Hoagland *et al* (5) have postulated a competitive effect in ionic penetration. They suggest that, through competitive action of ions of similar charge, one cation may depress the absorption of another, while an active anion may retard the absorption of the less active. Furthermore, the rate of absorption and accumulation of a cation is increased by a rapidly absorbed anion.

The marked decrease in the accumulation of potassium in the tissue when nitrogen was supplied as NH_4^+ as compared to that when nitrogen

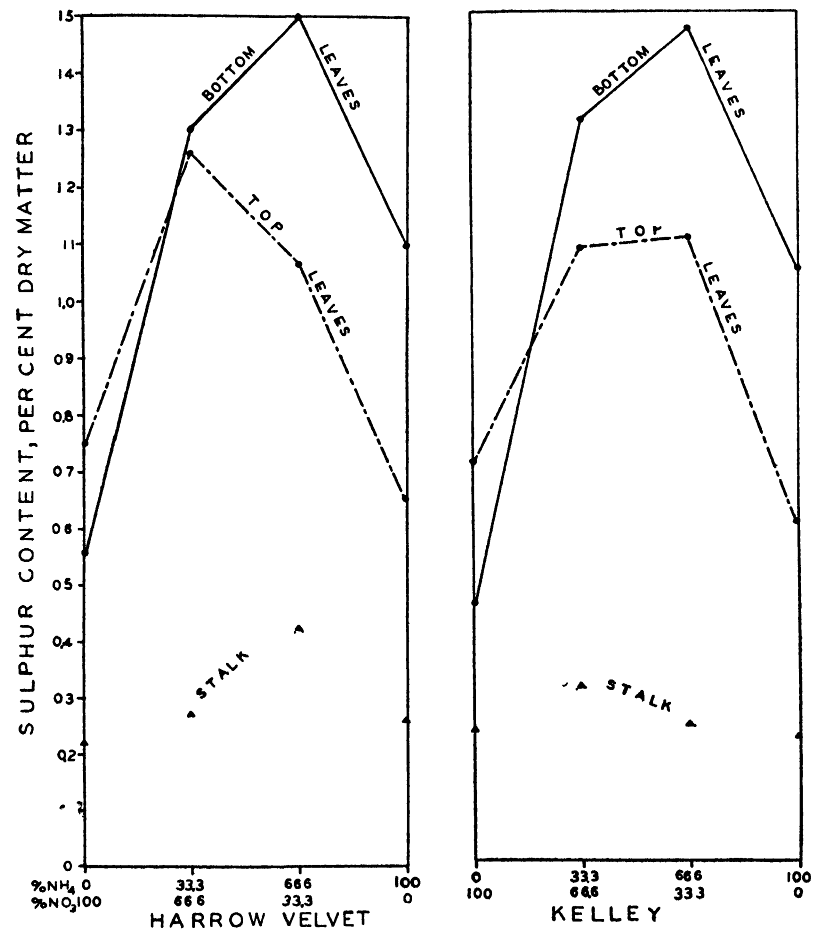

FIGURE 7. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of sulphur in tobacco tissue.

was supplied as NO_3^-, may be explained on a basis of Hoagland's hypothesis of ionic penetration. The presence of cation nitrogen (NH_4^+) in the nutrient solution seemed to decrease the rate of absorption of the K^+ ions of similar charge by interionic competition. Furthermore, the concentration of NO_3^- in the nutrient solution is a factor to be considered since the rate of absorption of potassium, a cation, may be accelerated by the absorption of the mobile anion, NO_3^-.

Figure 5 shows that, in all 3 fractions of the tissue, increasing content of calcium, a slowly-absorbed cation, was directly related to increasing NO_3^- concentration in the nutrient solution, and inversely related to increasing concentrations of the cation, NH_4^+, in the solution. Both relations are in harmony with the hypothesis of ionic penetration. These results are in close agreement with those of Jacobson and Swanback (7) who report that an increased proportion of nitrate nitrogen over ammonical nitrogen in the nutrient supply was associated with high calcium in the plant material of tobacco.

The analytical data, showing that the concentration of magnesium in the leaf tissue was low when nitrogen was supplied as NH_4^+, as compared to that when nitrogen was supplied as NO_3^-, present confirmatory evidence that the chlorotic condition of the plants grown on high NH_4^+ supply was correctly diagnosed as magnesium deficiency. These results throw further light on the magnesium hunger, or "sand drown," picture under certain field conditions. It was reported by Anderson *et al.* (1) that magnesium hunger was very severe on tobacco plants grown on plots to which nitrogen was applied as sulphate of ammonia. In explanation, these workers suggested the possibility of the magnesium combining with the sulphate radical, forming magnesium sulphate, a highly soluble salt, which later was leached from the surface soil by the heavy rain. In this regard, it seems highly significant that, in the present sand-culture experiment, magnesium hunger was associated with high ammonium nitrogen in the substrate under conditions which precluded the possibility of a deficiency of magnesium being created by leaching. Here, magnesium, as well as the other nutrient elements, was supplied continuously by the constant flow method.

The influence of ionic forms of nitrogen on the accumulation of magnesium in the plant is explainable according to Hoagland's hypothesis of ionic penetration. Figure 6 shows that the accumulation of magnesium in both top leaves and bottom leaves was accelerated by increase in the concentration of the mobile anion, NO_3^-, in the nutrient medium, but was retarded by increase in the concentration of the NH_4^+ ion because of interionic competition. That is, the rate of absorption of magnesium, a slowly-moving anion, was increased by the presence of nitrate, a rapidly-moving anion. Conversely, the rate of absorption of magnesium was retarded by the competitive ionic penetration of the other cation, NH_4^+. Both relations conform to Hoagland's hypothesis.

Phosphorus was a variable factor in the nutrient supply. In the stalk and top leaves, which include the regions of most rapid growth, the content of phosphorus was directly related to the concentration of this element in the nutrient medium. Also, in these fractions, the content of phosphorus which is absorbed as an anion was directly related to the concentration of

cation nitrogen and inversely related to the concentration of anion nitrogen in the substrate, in accordance with the hypothesis of ionic penetration. However, no definite relationship was manifested between the content of phosphorus in the bottom leaves and either the ionic forms of nitrogen in the nutrient medium, or the concentration of phosphorus in the nutrient medium.

Sulphur, also, was a variable factor in the nutrient supply; however, the content of this element in the tissue did not vary in proportion to its concentration in the nutrient supply. Also, the relationships between the ionic forms of nitrogen, and the accumulation of sulphur in the plant, are not in full agreement with the general hypothesis of interionic relations.

The results of the chemical analyses show a difference between the metabolism of nitrate nitrogen and ammonium nitrogen in both varieties. When nitrogen was supplied as NH_4^+, there was an increase in the accumulation of total nitrogen in all 3 fractions of the tissue over that when nitrogen was supplied as NO_3^-. This result, coupled with the relatively poor growth made on ammonium nitrogen, is indicative of inefficient ammonium-nitrogen utilization by the burley tobacco varieties tested.

It is evident that the concentration of ionic forms of nitrogen in the nutrient medium had a significant influence on the content of the major nutrient elements in the tissue of burley tobacco at harvest; however, the varietal differences in this regard were insignificant. Moreover, the interionic relations herein shown to exist have been demonstrated for only the 2 tobacco varieties tested, and only under the conditions of this experiment. The responses of other varieties to the same treatments, and the responses of the same varieties under different conditions, could be determined only by further study.

SUMMARY

Two varieties of burley tobacco, namely, Harrow Velvet and Kelley, were grown in sand culture on a range of nutrient solutions made up of varying proportions of nitrate and ammonium nitrogen. The differential response by varieties to the 2 ionic forms of nitrogen was not statistically significant. One variety did not make relatively more growth on nitrate nitrogen, compared to its growth on ammonium nitrogen, than did the other variety.

The varieties and treatments were both sources of significant variation; Harrow Velvet yielded higher than Kelley, and both varieties yielded lower at the ammonium end of the solutions.

Top leaves, bottom leaves, and stalk tissues of each variety from each treatment were analysed for total N, P, K, Ca, Mg and S. While the content of these elements in the plant material was greatly affected by the relative proportions of the ammonium and nitrate ions in the nutrient medium, the varietal differences in this regard were insignificant.

It was determined that the ionic forms of nitrogen in the nutrient medium had either a positive or negative effect on the content of the elements in the tissues, in agreement with the hypothesis of interionic relations advanced by Hoagland *et al.* An increased proportion of nitrate nitrogen and a decreased proportion of ammonium nitrogen in the nutrient solution, resulted in an increase in the content of K, Mg, and Ca and a decrease in the content of N and P in the plant material.

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SEED POTATO DISTRICTS AND VIRUS DISEASES IN QUEBEC[1]

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In 1928, trials were undertaken to determine: the districts most suitable for the growing of certified seed potatoes; the possibilities of maintaining in a district certified seed commercially-free from virus diseases; if certified seed grown in one district could be grown advantageously in another district; to what extent virus diseases had either spread or decreased in the tuber unit seed plots in each district; and the reasons why the truck crop and potato growers in the vicinity of Montreal preferred changing their seed each year.

In 1932, these trials were discontinued on account of the impossibility of visiting the same regularly and at the proper time for the examination of virus diseases. Field inspection of these plots could be made but twice during the growing season and then often under unfavourable conditions brought about by the damage to the foliage caused by insects, fungous diseases and the effects of late planting. These difficulties sometimes rendered it impossible to determine accurately the exact percentage of virus diseases in the plants.

At the suggestion of Mr. John Tucker, formerly Seed Potato Specialist for the Dominion Department of Agriculture, the author decided during the winter of 1938–39 to index potatoes from these plots in order to determine, as accurately as possible the percentage of transmission of virus diseases by sucking insects during the previous growing season. The tuber index method was chosen because other methods of detecting virus diseases were found quite unsatisfactory for this kind of work.—In 1938, very few tubers from these plots were indexed due to lack of space in the greenhouse at the local plant pathological laboratory.—In 1939, the Potato Section of the Horticulture Service of the Quebec Department of Agriculture erected at Ste. Anne de la Pocatiere, at the Agricultural School, two greenhouses 66′×25′. In these greenhouses the tuber indexing work (2) was carried out in co-operation with the provincial officials.

GEOGRAPHICAL DISTRIBUTION OF SEED POTATO DISTRICTS

In 1928, when this work was first undertaken, the Province of Quebec was divided into 5 districts. District Number 1, comprised seed potato centres located in the southern and the south-western parts of the province, that is to say, those areas between the 45° and 46° N. District Number 2, included the seed potato sections in the eastern, central and western parts of the province located between 46° and 47° N. District Number 3, comprised the parishes located in the eastern and central parts of the province situated between 47° and 48° N. District Number 4, included all the parishes growing potatoes located in the northern, north-eastern and north-western parts of the province including the areas located between 48° and 49° N. District Number 5, grouped all seed potato growing sections located above 49° N.

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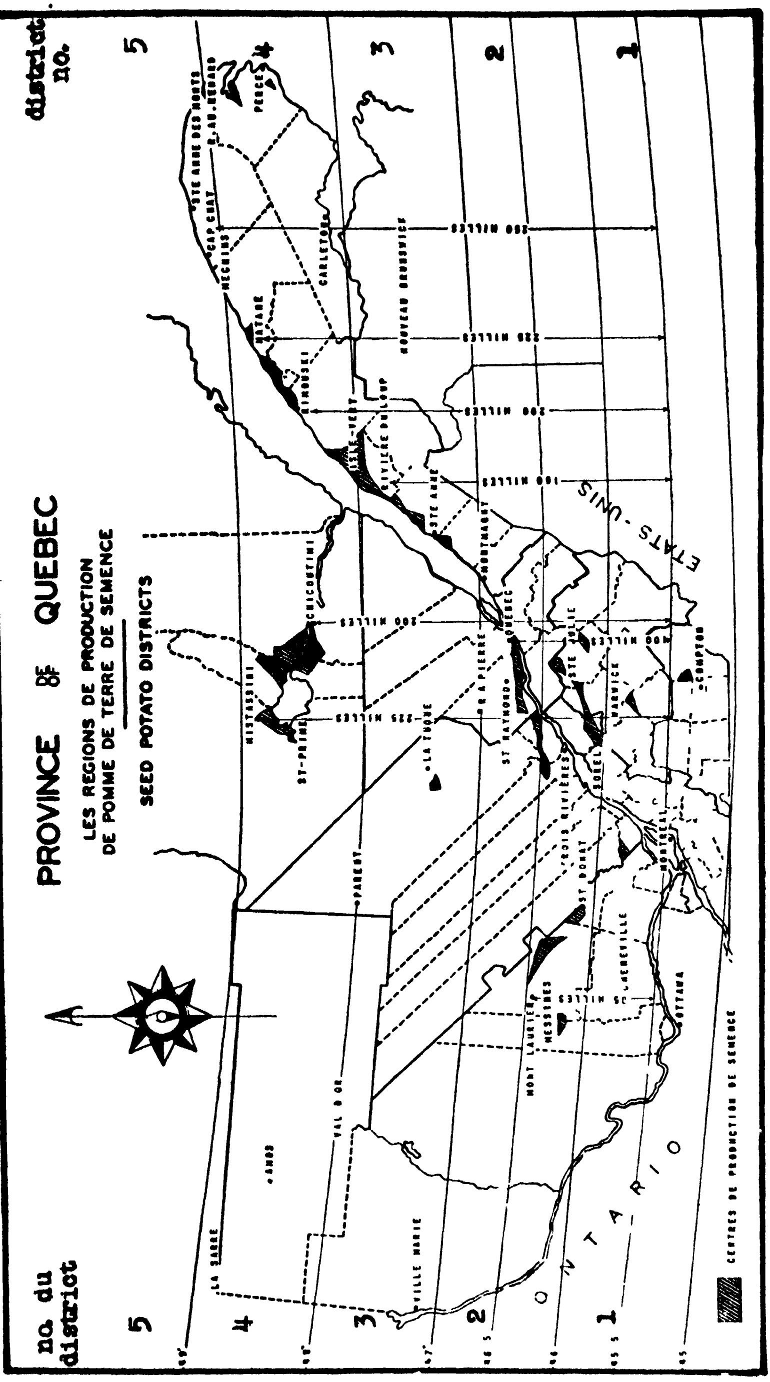

FIG. 1. On this map the striped diagrams indicate in each district where the trials were conducted. It is pointed out that some seed potato centres such as Mistassini, Chicoutimi, Rimouski and Matane are located over 200 miles north of Montreal which is on the 45.5° N.

There were a certain number of seed potato growing centres in each district and trials were conducted in each centre. Locations of these seed potato centres may be seen on the map which follows.

When this work was first undertaken, a survey was conducted in each district, to obtain information on the acreage planted with certified seed and inspected with the view to certification. The total acreage inspected in the Province of Quebec is 2,200 acres. Table 1 shows the percentage of acreage of certified seed inspected in each district during the years 1929 to 1932 compared with the period 1942 to 1945.

TABLE 1—AVERAGE % ACREAGE OF CROPS INSPECTED AND CERTIFIED IN EACH DISTRICT

District No.	Average % acreage inspected during the years		Average % acreage certified from 1942 to 1945 in the grades (1)		
	1929 to 1932	1942 to 1945	F	F-A	C
1	17.5	8.0	1.9	3.40	8.1
2	35.0	25.5	42.6	16.15	54.8
3	5.0	12.0	9.9	16.50	9.8
4	41.0	54.0	45.6	63.70	27.3
5	1.5	0.5	—	0.25	—

(1) 'F'—Foundation 'F-A'—Foundation A 'C'—Certified

The Foundation and Foundation-A grades of certified seed potatoes were not established until 1942. Only one grade "Certified Seed" was known previous to 1942.

Table 1 shows that from 1929 to 1932 inclusively, 47.5% of the total production of certified seed potatoes was grown in districts 3, 4 and 5. The figures for the years 1942 to 1945 inclusively show that 66.5% of the acreage was grown in the same districts indicating an increase of 19% in the production of certified seed potatoes in the districts located above 47° N. Certified seed production in District Number 5 decreased 1% during the period 1942 to 1945. This was due largely to the occurrence of the scab disease which rendered the potatoes unsuitable for seed purposes. The data in Table 1 also show that 45.6% of the Foundation, 63.9% of the Foundation-A and 27.3% of the certified grade seed potatoes was grown in Districts 4 and 5. It is also significant that 62.9% of the Certified grade was grown in Districts 1 and 2 located in the southern, south-eastern and the south-western parts of the province between 45° and 46° N.

In the districts where these trials were carried out, the plots were planted exclusively with tuber-indexed seed of the Green Mountain variety. The only exception was in District Number 2 where about 50% was of the Irish Cobbler variety. On the farms where these trials were conducted only Foundation, Foundation-A and Certified seed potatoes were planted and inspected with the view to certification. These plots were planted at distances varying from 200 to 1000 feet from table stock potato fields. Only one plot was planted on each farm and in the same district plots were often located a few miles from each other. The plots were planted by the tuber unit method and the size varied from ¼ to 1 acre. The first roguing of these tuber unit plots for removal and destruction of diseased units was

made at the beginning of July before sucking insects (aphides) appeared. In these trials, no insecticides were used to control aphides nor herbicides to destroy potato tops before complete maturity. On the majority of farms Bordeaux mixture was used for the control of late blight. The plots were usually harvested 10 to 15 days after the tops matured about the end of September or middle of October. The tubers from these plots were stored separately from other stocks. The grower in each case chose (according to the size of his plot) from 400 to 1200 tubers weighing from 6 to 10 oz. each. These tubers were sent in December to the Ste. Anne de la Pocatiere greenhouses for indexing in order to determine the amount of infection with virus diseases.

The tuber-indexing began early in January of each year. Each lot indexed comprised tubers from the plots in each district. The final readings on plants in each lot were made in February, March and April. The mother tubers (whose eyes had shown no disease in the greenhouse) were returned to the grower for the planting of his tuber unit plot the following season.

RESULTS OF THE TRIALS

Table 2 shows the invasion of tuber indexed seed with mosaic and leaf-roll in each district during the period 1942 to 1946. The results of the trials conducted from 1939 to 1941 are not included in this table because it was not possible to determine accurately from the small number and restricted size ($\frac{1}{10}$ acre) of the plots used, the amount of virus disease in each case. No trials were made in District Number 5 but there were a few plots located in District Number 4 a few miles from the border of District Number 5 (Fig. 1).

DISCUSSION

The data obtained from these trials give at least a partial answer to the question of the most suitable certified seed potato districts. There is considerable evidence to show that in Quebec Province the prevalence of virus diseases (more especially leaf-roll) varies considerably from season to season, from district to district, and even from locality to locality. Local variation in the incidence of the leaf-roll disease suggests the necessity of determining and limiting, especially the areas used for the production of Foundation seed. Leaf-roll is undoubtedly a very important limiting factor in the production of seed potatoes. The rapid spread of this disease in some districts is believed to be due to an increase in the number of aphides late in the growing season. The figures in Table 2 indicate that the seasonal incidence of leaf-roll in the seed plots is greater in Districts 1, 2 and 3, than in District Number 4. The results of these trials during the years 1942 to 1946 show that in District Number 4 the average percentage of leaf-roll infection was 2.4 compared with 12.5 for District Number 1. These results also clearly indicate that there was less leaf-roll transmission in the seed plots grown closer to the north and north-eastern parts of the province. The above results confirm the findings of other workers, especially those of Folsom (3) of the United States.

Table 2 also shows that the mosaic disease varies from year to year and in a season from district to district and even from locality to locality. In general the percentage of mosaic was less than that of leaf-roll, except

TABLE 2.—SUMMARY OF RESULTS WITH TUBER-INDEXED SEED PLANTED BY THE TUBER UNIT METHOD IN DIFFERENT SEED POTATO DISTRICTS

Year	No. of district	No. of farms	No of bags (75 lb.) indexed seed planted	No. of tubers removed and indexed	Virus diseases found according to tuber-index test	
					Mosaic	Leaf-roll
					%	%
1942–43		1	2	340 (1)	1 47	2 15
1943–44	1	2	3	710 (1)	4 65	7 61
1944–45		3	5	2,109	3 13	5 12
1945–46		4	14	3,887	8 90	18 36
	Four-year average				6 40	12 50
1942–43		4	6	1,185 (1)	3 88	12 69
1943–44	2	2	8	473 (1)	2 98	2 96
1944–45		8	4	5,440	3 87	3 11
1945–46		9	34	4,462	2 89	6 47
	Four-year average				3 40	5.30
1942–43		9	39	5,825	4 33	8 03
1943–44	3	10	36	10,083	4 27	5 12
1944–45		7	63	6,115	3 24	3 99
1945–46		9	45	10,908	3 36	4 48
	Four-year average				3 80	5 20
1942–43		11	31	8,245	4 23	3 31
1943–44	4	14	52	6,464	2 40	2 72
1944–45		24	40	13,364	3 31	1 53
1945–46		35	84	20,327	3 58	2 56
	Four-year average				3 40	2 40

(1) An accurate determination of the amount of virus disease could not be made because less than 400 tubers from each seed plot were indexed in each case

in District Number 1 where seasonal variations were more pronounced. The average percentage of mosaic infection in the seed plots was 6 4, 3.4, 3 8 and 3 4 in Districts 1, 2, 3, and 4, respectively. These figures indicate that there was very little variation in the percentage of mosaic infection in Districts 2, 3 and 4 but the transmission of the disease in these areas was much lower than in District Number 1.

According to the date shown in Table 2, the location of a district or a centre, even a farm, may have an influence on the quality of the seed (1). It is apparent that seed grown in District Number 1 degenerates rapidly due to invasion by virus diseases, while that in District Number 4 shows very little evidence of these destructive diseases. These diseases even tend to eliminate themselves in some sections of this District. Our trials, observations and field inspections also demonstrate that it is undesirable to plant and multiply certified seed potatoes grown in Districts 1 and 2 in Districts 4 and 5 because such seed rarely qualifies for certification in the latter areas. This confirms the finding of other workers, especially Macoun (4), that northern-grown seed potatoes are preferable for seed purposes.

Table 3 includes figures taken from the annual tuber indexing reports (5) showing the average percentage of infection of mild and severe mosaic as well as severe and mild leaf-roll for each district.

TABLE 3.—AVERAGE % OF MILD AND SEVERE MOSAIC AND LEAF-ROLL IN EACH DISTRICT

District No.	Average % of virus diseases according to tuber indexing test(1)			
	Mild mosaic	Severe mosaic	Severe leaf-roll	Mild leaf-roll
1	4.2	2.2	1 80	10.7
2	2 9	0 5	0 60	4 7
3	3 1	0 6	0 10	5 0
4	3 0	0 4	0 02	2 3

(1) Four year average.

The results of the trials summarized in Table 3 reveal that the average percentage of infection of mild and severe mosaic varied from district to district. In District Number 1, the incidence of severe mosaic was nearly 6 times greater than that in District Number 4 and about 4 times higher than that in District Number 2. This indicates that mosaic increased as the seed plots were located towards south and south-western parts of the province.

The data in Table 3 also shows that the average percentage of severe leaf-roll infection in District Number 4 is only 0 02 compared with 1.8 in District Number 1. There is an even greater difference in the incidence of mild leaf-roll in these districts being 2 3% in District Number 4 and 10.7% in District Number 1. These results revealed that the leaf-roll disease increased as the seed plots were located in the southern section of the province. Therefore, the localities most suitable for seed selection and multiplication of potato strains would be those located above the 48° N.

A study of the tuber indexing reports on stocks from different localities in each District also shows that the total percentage of virus disease varies from one locality to another and often differs in a season from one farm to another. It was found that in some localities in the same district the amount of leaf-roll infection was negligible and even tended to disappear. It was also discovered that the mosaic disease varied in the same locality which seems to prove that there are sections in the same districts, more especially in District Number 4, where ideal conditions exist for the multiplication of Foundation seed stocks. These favourable centres are often well isolated and restricted in size.

On the basis of these findings it would be advisable to choose from these preferred centres the areas most suitably adapted to the growing of Foundation seed stocks. Owing to the fact that certain fruit trees, shrubs and weeds serve as overwintering hosts for the aphides which transmit leaf-roll and mosaic, these hosts should be located and destroyed in the areas chosen for the Foundation seed production.

SUMMARY AND CONCLUSION

Certified seed production in the Province of Quebec is centered in 5 main districts. Trials were conducted on 40 farms in 25 localities in these districts to determine the areas most suitably adapted to the growing of Certified seed potatoes, especially the Foundation and Foundation-A grades.

The results of these trials showed that the production of seed potatoes is gradually shifting in a north and north-easterly direction in the Province. Fifty-four percent of the certified grades of potatoes are now grown above 48° N.

The methods employed in connection with these tests were essentially the same each year. The seed potatoes used for these trials were all tuber-indexed in the greenhouse the preceding winter and only disease-free tubers of the Green Mountain and Irish Cobbler varieties were chosen. All the plots were planted according to the tuber unit method. The total number of tubers removed in the fall from each seed plot and indexed ranged from 400 to 1200 according to the size of the plots. The plots varied in size from $\frac{1}{4}$ to 1 acre. The percentage of virus infection in each generation was determined during the winter months in the greenhouse by the tuber-index method. From 16,000 to 39,000 tubers were tested annually which represents that each year from 125 to 300 bushels of seed potatoes from 25 parishes of this province were subjected to the tuber-index test.

The results of these trials including those from the field and tuber-index tests showed that the incidence of such disease as leaf-roll and mosaic varied according to the season, district, locality and isolation conditions. It was apparent that the leaf-roll disease increased as the test plots were grown closer to the south and south-western parts of the province. The fact that conditions in this section of the province enhanced the occurrence of the leaf-roll disease, explains in part at least, why growers in the Montreal district found it necessary to change their seed potato stocks every year to ensure a supply of seed free from this important virus disease. The transmission of severe mosaic disease decreased as the plots were located towards the north and north east. Noteworthy, is the fact that leaf roll tends to eliminate itself in certain districts.

In these trials we have noted that, in general, in cool regions which are hilly, and have a high elevation, if potato fields are far apart better seed is produced than in warmer sections which are level, lower and in which fields are close together.

The results of the several trials definitely indicated that it is in the north and northeastern districts as well as those which are in proximity to the sea that the growing of certified seed potatoes, especially the Foundation grades, should be intensified. In the less favourable districts, especially in the south and south-western parts of the province, certified seed growing should be discontinued and the production of table stock potatoes encouraged.

Worthy of mention in connection with these trials is the fact that Bacterial Ring Rot was never found in the tuber unit seed plots or in the greenhouses during the course of these trials. This seems to indicate that the combination of tuber-indexing and tuber unit planting may be a practical means of controlling this important disease.

It is hoped that the information accumulated in connection with these trials will serve as a useful guide to the establishment of centres most suitably adapted for the growing of certified seed potatoes, especially the Foundation grades.

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ERADICATION OF POISON IVY (*RHUS RADICANS* L.)

II. PRELIMINARY RESULTS WITH 2,4-DICHLOROPHENOXYACETIC ACID[1]

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Recent interest in the herbicidal activity of phenoxyacetic acids has resulted in considerable experimental work to evaluate their weed killing properties. In 1945, at Ottawa, 2,4-dichlorophenoxyacetic acid was included among the herbicides being tested for the eradication of poison ivy. The results obtained from the 1945 trials are of sufficient interest to be placed on record. Further experiments are underway and will be reported when complete results are obtained.

All applications were made as an aqueous spray to the poison ivy foliage by means of a knapsack sprayer of 3-gal. capacity. The experimental plots were 100 sq. ft in area and were situated at Wrightville, Quebec, on very shallow soil over limestone bedrock. They were on a railroad right-of-way, and the edge of some of the plots included the slight shoulder of fill by the tracks. The aqueous spray solutions were prepared by dissolving the required amount of 2,4-dichlorophenoxyacetic acid in melted carbowax 1500, then adding this solution with stirring to the gallon of water. The carbowax was used in amounts sufficient to give a 0.5% solution regardless of the concentration of 2,4-dichlorophenoxyacetic acid. The gallon of solution was sufficient to cover each plot twice.

Estimates of poison ivy cover were made visually and represent the percentage of the area of the plot covered with poison ivy foliage.

The results obtained are given in Table 1

From the estimates of poison ivy cover made in July of the summer following the application of 2,4-dichlorophenoxyacetic acid, it is apparent that best results were obtained when the acid was applied to young plants in June and in concentrations of 1000 p p.m or greater.

TABLE 1.—THE EFFECTIVENESS OF 2,4-DICHLOROPHENOXYACETIC ACID AS A HERBICIDE WHEN APPLIED AS A SPRAY TO POISON IVY PLOTS OF 100 SQ. FT. IN AREA

Exp. No.	Plot No	Date of application	Amount of herbicide applied		Poison ivy cover (%)	
					Before treatment	In July of first year after application
		1945	gal.	p p m.		
21	9	June 26	1	250	80	35
	10	June 26	1	500	85	30
	11	June 26	1	1000	85	5
	12	June 26	1	2000*	90	5
22	2	June 25	1	1000	85	10
	4	July 18	1	1000	95	75
	6	Aug. 9	1	1000	90	80
	8	Sept. 12	1	1000	85	80

* A precipitate occurred when carbowax containing this amount of 2 4 dichlorophenoxyacetic acid was dissolved in water Herbicidal strength therefore would be less than 2000 p p m.

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BOOK REVIEW

THE NEW GENETICS IN THE U.S.S.R.—P. S. Hudson and R. H. Richens, Imp. Bureau of P.B. and Genetics, Cambridge, 1946, pp. 88.

During the past ten years or so there has been much confusion in the minds of people on this continent and elsewhere regarding a school of thought which has been developing in the field of genetics in the U.S.S.R. This school, led and vigorously defended by Lysenko and Prezent, differs profoundly from that recognized by the majority of modern biologists. It is based on a philosophy—in this case the philosophy of dialectical materialism—rather than on conceptions commonly held by scientists outside of Russia. It is definitely opposed to the Mendelian theory, partly because this theory lends support to the opponents of those who are trying to defend the theory of social equality. The points of view held by the two schools, therefore, have led to controversies which have been extended far beyond the borders of pure science. Prezent himself says that "anyone who does not understand the enormous social-class significance of our controversy will fail to understand the essence of our controversy."

The Imperial Bureau of Plant Genetics has followed closely the developments which have been taking place and has published abstracts from time to time of the leading works published in Russia. The present bulletin, however, is the first real attempt to present a complete and impartial story and to submit the claims made to a careful scientific analysis. The authors have rendered a distinct service to a wide range of readers by clarifying the Russian points of view and in examining their validity.

Those interested in this question should read the bulletin carefully. They will find it extremely well written and most thought-provoking. An excellent and much more complete review of this bulletin by Prof. Eric Ashby appears elsewhere so no extended comments need be made here.*

Prof. Ashby not only discusses the salient points raised by the authors but supplements these from his own personal observations. Thus he is able to furnish first-hand information as to the experimental technique employed by Lysenko and his followers This by all modern standards recognized outside the U.S.S.R. must be regarded with suspicion. He expresses the opinion that the Lysenko school is on the wane and that most biologists in the U.S.S.R. have actually been embarrassed by the claims made therefor.

L. H. NEWMAN

ERRATA

In the September issue of Scientific Agriculture (Vol. 26, No 9, 1946) amend the second paragraph on page 424 to read as follows.

The equipment described has been used for colour photography, and some examples have been published elsewhere (4). Kodachrome professional type B film, having a colour temperature rating of 3200° K (1, 5) and a film speed of 6 Weston units, was used.

In the same issue, amend the last sentence on page 445 to read as follows: If a dryer is not available, Tests 8, 9, and 10 are suitable, although the drying time of the samples will range from 12 to 20 hours respectively, for each test.

*Ashby, Eric, Prof. Genetics in the U S S R *Nature*—MacMillan & Co Ltd. St Martin St, London WC 2, Vol 158, No. 4009, p 285